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World-Wide Responsibilities of Technical Book Authors*

By JAMES S. THOMPSON

Executive Chairman of the Board, McGraw-Hill Book Company

In venturing on this science program, as a book publisher, I hope the listeners understand my awareness of my qualified position. Howard Mumford Jones, in the New York Times recently, in reviewing that splendid volume commemorating Scribner's 100th Anniversary, OF MAKING MANY BOOKS, spoke of the publisher as a "midwife to genius." For tonight, I might change to a more technical term, calling myself merely a catalytic agent, i.e., one who brings together two separate elements as in chemistry, the author and his reader, but not always as in chemistry remaining himself unchanged from the experience. Indeed it surely influences one's outlook to spend a whole lifetime in contact with such geniuses as General Electric's original great wizard, the late Charles Proteus Steinmetz, whose several volumes were translated into many languages, and others who have followed him.

The publisher would indeed be dull in handling scientific and technical books , to be insensitive to the ideals of these authors. I have in mind their high standards as to accuracy of statement, the months and sometimes years of effort in study and research to be sure the manuscript is comprehensive, fully documented, cross-referenced as to illustration references and all the other minutias that are routine but vital in finishing a work that definitely will never rate the best-seller lists, nor put the author glamourously at book-and-author luncheons. He knows, on the other hand, that placed in the hands of just the right persons in any country or community it may help to raise the standard of living of a whole people, reduce mortality, dramatize obsolescence, save a company millions in operating costs, inspire countless teachers in more effective technique, accelerate communications and transportation standards—bring nationals of many countries closer together through study, reading and better understanding of each other. In a word, that is my theme—that such authors may well rate as ambassadors between countries; that a technical publisher is fully warranted in adopting a dynamic vital slogan—"World-wide distribution despite language barriers."

Scientists individually know no international political barriers. It was at the end of the first World War when the scientists of the Allies united in an effort to prevent Germany again from acquiring a monopoly in books of certain vital scientific information. It was American, British, French, Italian, Danish, Dutch, Austrian, Swiss, Bel-

* This talk was delivered on December 4, 1946, during the General Electric SCIENCE FORUM, program—a weekly broadcast on Wednesdays, from Schenectady, N. Y., over WGY (810 kc.) at 7:30 P.M.

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gian and Japanese who collaborated then to produce the International Critical Tables of Physical and Chemical Constant—an 8 volume, large-page, four-language encyclopedia of research results from the labors of a vast army of physicists, chemists and others here and abroad.

In the second World War, in the development of the atomic energy project, there was, as everyone knows today, similar cooperation among scientists whose origins geographically were quite remote from each other. And a resulting book, ONE WORLD OR NONE, which is appearing in many languages is also an example of international authorship with common bases in science. In this case the authorship included four Nobel Prize winners who joined with others in an effort to awaken the people of the world to dangers inherent in an absence of *complete* international harmony. Dr. Langmuir of General Electric contributed a brilliant, candid chapter on our relations with the Soviet on this profoundly hazardous question. However, the official, elaborate review in *New Times* published in Moscow in September 1946 concluded with a paragraph which definitely qualifies the practicability of my theme this evening. It says:

"Its contents may serve as an illustration of what Karl Marx so brilliantly foretold, namely that the productive forces of capitalism, including so powerful a productive force as science at a certain stage of development 'are no longer productive but destructive forces.'"

This political conclusion is of course a striking example of the chasm that separates Soviet thinking from ours in the United States. One would hope fervently that the vast library of all our technical literature—over $125,000 worth of books of all publishers which the Soviet has been purchasing during 1946—may counteract this one-sided political interpretation in the minds of Soviet counterparts of the U. S. authors and help to provide a common ground of understanding for mutual aid and peaceful progress.

Speaking parenthetically, technical book publishers in the United States are well aware of the brilliant scientific and engineering authorship of men of Russian birth. For example, Professor Stephen Timoshenko of Stanford whose several books in mechanics are available in many languages, holds the highest honor in American engineering education, the Lamme Medal. Among others are, Bakhmeteff of Columbia, Sokolnifoff of Wisconsin, and California, Maleev and Uspensky. We look for continued contributions by Russians in genetics, physics, biochemistry and cancer research. Reciprocal non-political publishing arrangements which are in progress of negotiation, when consummated, should be profoundly stimulating in education, science, and to authors both in the United States and abroad.

Another example of international scientific cooperation which is now about to appear in 28 volumes is that from the famous Radiation Laboratory of the Massachusetts Institute of Technology where over 500 scientists, including many from England, collaborated on profoundly important and secret research in radar and other electronic projects that helped to win the war. Now declassified with U. S. government approval, it is to be available to all the world. Already French and Latin American publishers have secured options on translations.

The war efforts as everybody knows, brought world-wide recognition of the abilities of United States industrial, technical and scientific workers. Results for peacetime developments continue to appear. Quite recently a native from the West Coast of Africa, well educated and at a New York university for graduate study, said, "Your troops building airports in our part of the world showed us a new way of life. New methods of doing things—new equipment to save labor—new controls for food, and sanitation and roads—in fact, we never knew how to spend money. I'm returning to my native country to distribute U. S. books and magazines that were never before available."

On another scale, international cooperation in encouraging technical book translations for national industrialization projects comes from France. At the International Technical Congress in Paris in September of this year, 1,200 prominent engineers and industrialists, representing 40 nations, passed resolutions approving in principle the reciprocal project which is developing between French and United States technical publishers. In France a professional committee prepared agenda of 23 subjects that were foremost in their national program for recovery. In the United States a professional committee representing engineering education, industrial research and a technical library, selected the best of our vast literature on these subjects.[1] It is believed here that the effort would eliminate waste and duplication, insure quality, help accelerate the program and eventually bring us in the United States knowledge of more French geniuses such as Curie, Pasteur, and Lavoisier, to mention only three.

This development by the way, traces back in part to the encouragement of a General Electric official. It was Mr. Earl Givens of the Rio de Janiero office who, among others, insisted during the war that the Rockefeller Committee for Coordination of Inter-American Affairs ought among other things to send a committee of representative book publishers to study the barriers that restrict inter-American book circulation. He believed strongly that greater availability in both Spanish and Portuguese, as well as English, of the best books throughout the Americas would help to greater understanding—not only for the war effort but for permanent peacetime acceleration of business, social and government relations. Five of us made such a trip by plane in 1943 and it was an education and an inspiration especially from the point of view of the technical publisher. Secretary Pedilla of Mexico and Education Commissioner Marshall of Chile were among the many officials educators, librarians industrialists who strongly endorsed the theme which Mr. Givens had submitted. Much good has come of that investigation, and results, which develop slowly and conservatively in technical publishing, are still appearing. Recently, out of a new appreciation of Latin American medical education, arrangements have been made for a North American edition of a book on HUMAN PHYSIOLOGY, by Dr. Houssay, a professor at the University of Buenos Aires. Authorities in the United States say it is immensely superior to any-

[1] The American Committee consists of:
Dr. Harry S. Rogers, President, The Polytechnic Institute of Brooklyn.
Mr. R. K. Honaman, Assistant Director of Publications, Bell Telephone Laboratories, Inc.
Mr. R. R. Hawkins, Chief, Science and Technology Division, New York Public Library.

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thing now available in English. Publication will provide a test of the reciprocal possibilities in international authorship. To have North America medical students appreciate through their textbook the high quality of instruction in the Argentine should aid better inter-American understanding.

Various professional and government agencies have assisted through nominal sponsorship as well as funds to help spread abroad awareness of the United States potentials in science and technology. The National Research Council assisted publishers and other agencies to produce last year the first annotated bibliography of the best technical, scientific and medical books, 6,000 volumes, produced in the thirteen years prior to 1944. Nothing like it had ever appeared before. Our State Department sent a portion of the edition throughout the world. Copies have gone also to the many American Libraries and cultural centers which we maintain in 114 cities outside the United States. Last summer in both London and Paris I saw these libraries and always they were crowded with people seeking from their reference shelves information on American methods and institutions, and I suppose knowledge of what you might call "the American way of life."

The post-war spread of use of the English language and the demand for books and magazines on American technology is in fact not only impressive but pathetic. Of course the paper and labor shortage in publishing is still a great handicap to European publishers. However, it is indeed interesting to note that German has been dropped in favor of English as the second language in the Scandinavian countries and in Denmark and Holland. Furthermore, correspondence from North and South Africa, India, Australia, indicate the same new interest and confirmation for an argument that the U. S. author of a technical book that is properly handled today has a much wider audience than ever before. And the awakening is not confined to remote areas. The war, with many enforced limitations, jarred loose some very strong prejudices and traditions. It was indeed stirring to have a Professor of Electrical Engineering in a prominent British university say to me last summer, "No, I will not return to the use of the British textbook. Your American author has shown me a new teaching technique that I could not abandon." And to know that in that famous institution—Cambridge University—there have been in use during the last year, 61 textbooks in science and technology from one New York publishing house, and that a new department of Chemical Engineering modeled after the famous curriculum based on unit process at the Massachusetts Institute of Technology is about to open—should be adequate evidence that the Atlantic Ocean has shrunk to nearly nothing as a barrier in methods in engineering education.

All of which brings us to the question of students from abroad, who to the total of 45,000 tried in vain to enter U. S. colleges and universities this year. Before the war, 8,000 entered annually. Totals grew during the war to a top figure of 15,000 for the current academic year. The chief reason for barring the 45,000 is of course the well-known overcrowding that is currently barring thousands of our own including veterans whom our government is financing through college. One reason for the pressure from abroad is said to

be the appalling war devastation of their libraries. And I would end this talk with an appeal on their behalf. The results of the Nazi frenzy were of course tragic as respects book and printing equipment. In Paris in 1945, a year after the liberation I saw in Brentano's that the April 1940 issue of *Electronics* was their latest. Imagine here in Schenectady how it would be to have only Nazi literature on your newstand for five years, and then with the war over only a trickle of printed matter for months on end. You would turn to your library for some escape; but there *is* no library. I speak for the Publishers' Committee which is trying to help a national movement which is sponsored by the nine well-known (in fact, all) official library associations. You are begged to send surplus sets of bound volumes of periodical literature, both new and old editions, especially technical and scientific in subject-matter. Just ship your books to:

AMERICAN BOOK CENTER
C/o Library of Congress
Washington 25, D.C.

I appeal to educational authorities and to individuals as well for an examination of your shelves of surplus literature.

Another argument for helping to restore libraries is that thus one can participate definitely in the ideological warfare which is evidently to be with us for a long time and is to be especially active in Europe.

As Dr. Suits of the General Electric Research Laboratory said recently at the *Electronics* conference in Chicago "We are only on the frontiers of knowledge, without the slightest idea of the results to be expected and with experiences ahead at least as exciting as the exploration of power in the two or three decades just closed."

So, the technical book publisher as a catalyst looks forward to the international relations in which he and his authors may play a constructive part.

Mathematics in Civil Engineering*

By HAROLD E. WESSMAN

Chairman, Dept. of Civil Engineering, New York University

In opening my discussion this evening I should like first of all to congratulate those who arranged this joint meeting of mathematicians and civil engineers. It is a fine thing for these two groups to get together and exchange ideas, even though most of the ideas may be forgotten by the time the convention adjourns. In fact, the mathematicians should not take too seriously what the civil engineers say about the teaching of mathematics for we really are somewhat presumptuous in discussing the subject. We may be likened to the northerner who once visited Booker T. Washington, the great negro educator whose bronze bust has recently been placed in the Hall of Fame at New York University. The northern gentleman went to Tuskegee Institute and said to Booker Washington, "I would like to discuss race relations with you." Washington asked, "Have you ever lived in the South?" No, he hadn't lived in the South. "Do you own any land?" "No." "Well I'd like to suggest that you buy an acre of land down here in Alabama and farm it for a year. Then you come back and I will be glad to discuss race relations with you."

Before the war I had never taught mathematics. Nevertheless, like most engineers, I had definite ideas about the subject. Then came the war, the Army Specialized Training Program, and the dislocation of our normal engineering classes. Before long, four members of our staff in civil engineering, including myself, were teaching mathematics to engineering students. I had the pleasure of teaching analytical geometry, differential and integral calculus at various times before the war ended. I enjoyed the experience tremendously but I must admit that my previous opinions about mathematics underwent some modifications. For one thing, it influenced the title of this paper. Four years ago the title would have been "Civil Engineering in Mathematics," a title which undoubtedly has more sales-appeal but is not as relevant to my paper as the more obvious and commonplace title which was chosen. My thought here is clearer to you when I say that four years ago I was in that group which believed that more engineering applications should be introduced into the fundamental mathematics courses. Now I am not much concerned about that.

In considering the topic of mathematics in civil engineering, some of the questions which present themselves for discussion are:

"How much mathematics should be included in a well-balanced undergraduate curriculum?"

* Presented at the Conference on Mathematics, S.P.E.E. meeting, St. Louis, June 20–23, 1946.

"What should be the time or credit allocation to each subdivision?"

"Should each branch, such as algebra, analytic geometry, differential calculus, integral calculus, and differential equations, be taught as separate courses or should the entire content be scrambled into what is sometimes called 'Unified Mathematics'?"

"Should the mathematics teacher try to make his course one in applied mathematics or should he ignore this pressure which comes from so many engineering teachers?"

The answer to the first question is one on which there is apparently a great difference of opinion. How much mathematics should be included in the civil engineering curriculum? Some engineers would have us study critically the types of work which the civil engineer does and give him only the necessary training in those mathematical tools which he uses most frequently. If we were to be guided solely by such a viewpoint we would probably stop with arithmetic because most of the mathematical operations performed by the civil engineer involve simple addition, subtraction, multiplication, and division. Others would say, "Well, the civil engineer occasionally uses algebra and trigonometry and some analytic geometry, but as a rule he doesn't use much calculus, so why waste any time on calculus?" Those who think in terms of the training needed for graduate study and research would require several advanced courses in calculus and differential equations.

Statistics are of some value and undoubtedly they constitute a source of comfort to those whose opinions are buttressed thereby. I am a member of the Committee on Civil Engineering Education of the American Society of Civil Engineers. Two years ago we made a survey of the allocation of time to various subjects in the civil engineering curricula of the 114 institutions then accredited by E.C.P.D. The range in mathematics was quite revealing. The lowest requirement in terms of semester hours was 9 and the highest requirement was 24 semester hours. However, the great majority of institutions devoted from 15 to 18 semester hours to mathematics courses. As a result of this study, our A.S.C.E. Committee recommended that 10 per cent of the curriculum should be devoted to mathematics, not including trigonometry. For those schools requiring from 140 to 150 semester hours for graduation, this would mean 14 to 15 semester hours for mathematics. This is sufficient to cover algebra, analytic geometry, differential calculus, and integral calculus. If a 3-point course in elementary differential equations is included for civil engineers—and I wish this could be done—then the total semester hours devoted to mathematics would be 17 or 18. The A.S.C.E. Committee felt, however, that it was not possible to increase basic science requirements and at the same time incorporate the desirable humanities content in a four year course without sacrificing some of the necessary fundamental engineering content. This we did not wish to do. Hence the recommendation of 10 per cent for mathematics will not permit the inclusion of differential equations. The percentage cannot be increased unless the 20 per cent of time recommended for humanities is reduced—or on the other hand, a five year course is adopted for an undergraduate degree.

Two years ago, our Civil Engineering Staff at New York University seriously considered the inclusion of a required 3-point course in differential

equations to be given in the first term of the senior year. We believed this course to be highly desirable, not only because so many of our students come back subsequently for evening graduate study, but primarily because such a course makes a student review thoroughly his basic courses in algebra, geometry, and calculus. There is a value in overturning the mathematical tool kit occasionally in order to get acquainted with the best tools for the various engineering problems which occur in practice.

But when we studied the proposal in relation to existing courses in the curriculum and in relation to another proposal for a unified humanities sequence to be given during the last four terms to all of our engineering students in the university, we reluctantly abandoned the idea of adding differential equations as an undergraduate requirement in civil engineering. All of our curricula now include a required 3-semester hour course in humanities in each term of the junior and senior years, and even though this sequence is admittedly experimental and subject to modification, it will not be possible to add also a required course in differential equations. The semester load is already too heavy, particularly for those of our students who travel long distances daily in the Metropolitan Area to and from the university.

I doubt if any university with a four-year program in civil engineering which is striving for the goal of a 20 per cent humanistic stem of studies can devote more than 14 to 15 semester hours to mathematics and achieve a desirable balance of content in the basic sciences and the basic engineering subjects. Let it be emphasized that I am discussing a civil engineering curriculum and not one in electrical engineering or engineering physics.

How should the total time allowance for mathematics be divided among the various branches? I have already indicated that a 14 or 15 semester hour allowance is sufficient to cover algebra, analytic geometry, differential calculus, and integral calculus. With 14 semester hours, I believe the desirable allocation is achieved by a 4-3-4-3 sequence in four successive terms. With 15 semester hours, the desirable sequence is 4-4-4-3. The difference between the two is in the amount of time assigned to analytic geometry. There is some question as to the need for a 4-point course in analytic geometry. Some believe that a 3-point course is sufficient to cover the necessary content needed by civil engineers. Frankly, I have no definite conviction on this point, although I am inclined to believe that if the topic of "curve-fitting and empirical equations" is given the attention which it deserves, the course requires a 4-point valuation. I would guess, however, that many teachers of analytic geometry slight this topic on the assumption that the derivation of empirical equations to fit experimental data is a matter fully discused in subsequent engineering courses. I am afraid their assumption is erroneous, for I doubt whether the majority of our mechanics teachers and our civil engineering teachers treat the subject adequately in those courses where experimental data are obtained and plotted.

Regardless of whether 3 or 4 semester hours are devoted to analytic geometry, I am thoroughly convinced that 14 semester hours of mathematics, excluding trigonometry, should be the minimum requirement for the civil en-

gineering student. If trigonometry has not been studied in the secondary school, the freshman student should take a 2-point course in this subject in addition to his other first year courses in mathematics.

I have little to say in answer to the third question, "Should each branch of mathematics be taught as separate courses or should the entire content be scrambled and portions of it dished out each term as a part of what is sometimes called 'Unified Mathematics'?" It seems to me that fundamental principles and ideas are obscured in the "scrambling process" and that moreover there is a tendency to "cover the whole water-front" in each term instead of concentrating on a thorough coverage of a few significant concepts. I may be "old-fashioned" in my view point about this, but it does seem to me that the traditional grouping into separate compartments of the basic principles and operations of algebra, analytic geometry, differential calculus, and integral calculus is to be preferred for the teaching of engineering students. It is hardly necessary to point out that each course in this sequence supplies background material for the following courses.

Let us now consider the fourth question, "Should the mathematics teacher make his course one in applied mathematics or should he ignore this pressure which comes from so many engineers?" We have all encountered statements such as the following, "If only our math teachers had studied electrical engineering. Then they could discuss the applications intelligently and our students would get much more from the math course."

As a result of my experience in teaching mathematics, I would say to the mathematics teachers, "Stop trying to be an electrical engineer or a civil engineer. You cannot be all of these and in addition be a good mathematician." And I would say to my engineering colleagues, "Do not criticize the mathematician. It is not up to him to teach applied mathematics. That is your responsibility in your engineering courses."

Now I hope that I will not be misunderstood. The engineers most certainly should cooperate with the mathematicians in preparing illustrative problems in engineering practice. In that connection, the work of John Cell and his committee in assembling and publishing "Engineering Problems Illustrating Mathematics" has been extremely worthwhile. But we must not expect the mathematician to give an engineering lecture in discussing such problems. In many cases, the student who may be majoring in any one of four or five different branches of engineering will only be confused by an incomplete lecture on the engineering phases simply because he hasn't the background to understand the engineering relations involved in the problems.

Here is an example of what I mean. The following problem might be introduced in a course in algebra as a practical illustration.

"In order to find the neutral axis of a reinforced concrete beam, the civil engineer writes an equation for locating the center of gravity of the transformed section. The resulting equation is a simple quadratic equation of the type $Ay^2 + By + C = 0$. A positive solution for y locates the position of the neutral axis."

Now any civil engineer who has taught the theory of reinforced concrete design knows immediately how difficult it would be for the mathemati-

cian to explain to a freshman engineering student the engineering concepts involved in this simple problem. It would be much better if the mathematician took the time to explain to his students the different ways of solving a quadratic equation in terms of abstract problems without trying to couple them with reinforced concrete design. At this point I would like to put in a plea for the solution of the quadratic by completing the square rather than by substitution of coefficients in the formal solution. I find that engineering students solve a quadratic by completing the square much more rapidly than they can do so by using the formal solution. Moreover they generally get the correct answer, whereas they so often make mistakes with the formal solution. I always have to give a lecture on completing the square because it seems as though they come from our algebra classes knowing only the formal solution.

In contrast to the preceding type of problem, a good engineering problem in analytic geometry is one which illustrates the finding of the equation for a curve which passes through three points. Most engineering students have seen arch bridges and if they are given a problem such as the following, little or no explanation of the engineering background is needed.

"A desirable shape for the axis of an arch is a parabola. If the arch has a span length of 100 feet and a height at the middle of 20 feet, what is the equation of the parabola that is to be used for the arch axis if the origin of coordinates is at the middle at the span and at the highest point of the arch? What is the equation if the origin is at one end of the arch?"

I could give other illustrations of what not and what to use. But the preceding problems suffice to bring out the point and I will conclude by expressing the hope that there will be some discussion on the questions which I have presented to you.

A Simple Demonstration of the Carrier and Side Frequency Components in an Amplitude Modulated Wave

By ALBERT D. BAILEY

Assistant Professor of Electrical Engineering, University of Illinois

An experiment of considerable interest to the student encountering modulation for the first time is a demonstration of the presence of the carrier, upper side and lower side frequency components of an amplitude modulated voltage or current. A conventional and direct method of demonstrating this involves the use of a frequency analyzer—a piece of equipment not always available to the ordinary experimenter. Below is outlined a simple but effective demonstration which utilizes only pieces of equipment readily available in the average laboratory. The required equipment consists of two audio-frequency oscillators, a non-linear element such as a *6H6* diode, a tuned circuit and a resonance indicator. An oscilloscope, a high impedance vacuum tube voltmeter or an electric tuning eye tube may be used for the resonance indicator.

From preliminary considerations of modulation theory * it is known that the application of two sinusoidal voltages of different frequencies connected in series across a non-linear circuit element will result in the production of a number of current components in the circuit. Among these current components will be the fundamental component of each input frequency and a modulation product component which is made up of the sum and the difference of the two input frequencies. The sum and difference frequencies are commonly called the upper and lower side frequencies respectively. If a selective circuit element such as a doubly-tuned, inductively coupled circuit resonant to the carrier frequency is now inserted into the circuit, considerable voltage may be developed across the tuned circuit element by the current components of frequency equal to, or near, the resonant frequency of the selective circuit element. A process of amplitude modulation is thus effected. Figure 1 represents such a process and is the basic circuit for the demonstration to be considered.

Each *L–C* circuit is first adjusted for parallel resonance at 5,000 c.p.s. Then the two coils are inductively coupled to obtain a condition approaching critical coupling. Next the approximate bandwidth of the selective circuit is determined by varying the frequency of the carrier oscillator, G_c, above and below resonance and observing the frequencies at which the reso-

* Reich, H. J., "Theory and Application of Electron Tubes," Second Edition, McGraw-Hill Book Co., New York, 1944, p. 293.

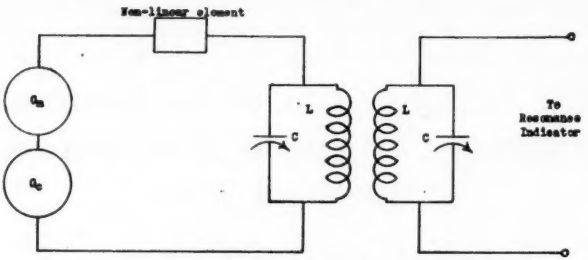


FIG. 1. A simple amplitude modulation process.

G_m Audio frequency oscillator simulating a signal or modulating frequency.
G_c Audio frequency oscillator simulating the carrier frequency.
L Laboratory inductance coil ($Q \geqq 15$ at 5,000 c.p.s.).
C Decade capacitor or equivalent.
Non-linear element—*6H6* diode or equivalent.

nance indicator shows considerably reduced response. The frequency of the signal or modulation oscillator, G_m, is adjusted to a value slightly larger than the bandwidth obtained above—1,000 c.p.s. is a convenient value for a $Q \geqq 15$. The amplitude of the output voltage of each oscillator is adjusted to approximately one volt.

The experiment consists of varying the frequency of the carrier oscillator from 3,500 to 6,500 c.p.s. first with G_m turned off and again with G_m turned on and operating at 1,000 c.p.s. and observing for each case the response shown on the resonance indicator. For the case of $G_m = 0$ (turned off) a single peaked response will be observed as the frequency of G_c is varied about 5,000 c.p.s. This is as expected. For the case of $G_m = 1{,}000$ c.p.s. (turned on) distinct peaked responses will be observed as the frequency of G_c is varied about 4,000, 5,000 and 6,000 c.p.s. respectively. The solid curve of Fig. 2 shows the observed differences in response obtained for the second case.

Remembering that the resonant circuit responds *only* to frequencies in the region of 5,000 c.p.s. the results of the second case are explained as follows: at the carrier frequency $G_c = 4{,}000$ c.p.s. the resonant circuit is responding to an upper side or sum frequency, that is, 4,000 + 1,000 = 5,000 c.p.s; at

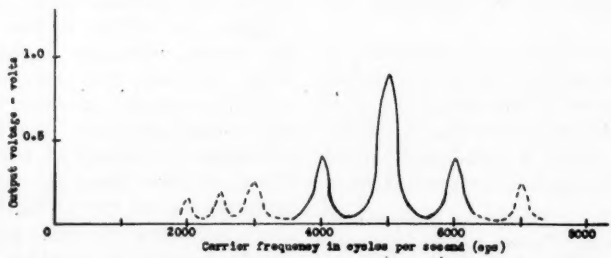


FIG. 2. Resonance indicator response vs. carrier frequency ($G_m = 1{,}000$ c.p.s.).

the carrier frequency $G_c = 5{,}000$ c.p.s. the resonant circuit is responding to the carrier alone; at the carrier frequency $G_c = 6{,}000$ c.p.s. the resonant circuit is responding to a lower side or difference frequency, that is, $6{,}000 - 1{,}000 = 5{,}000$ c.p.s. The magnitudes of the peaks observed approximate the magnitudes of carrier and side frequency components to be expected for 100 per cent amplitude modulation.

If the range of variation of G_c is extended beyond that indicated above, other peaked responses will be observed as indicated by the broken-line curves of Fig. 2. These responses correspond to harmonic and additional intermodulation frequency components attending such a modulation process.

Acknowledgement: The author wishes to thank Professor G. H. Fett for his critical reading of the manuscript.

Accrediting Agricultural Engineering Curricula — View Points of Agricultural Engineering Faculty Members

By GEORGE B. NUTT

Professor and Head, Dept. of Agricultural Engineering, Clemson College

Accrediting of agricultural engineering curricula has been a lively subject for discussion by members of the Society of Agricultural Engineers for at least a decade. For some time a feeling seemed to exist that requirements for accrediting were not fully defined. When the subject was discussed by Dean R. A. Seaton at the annual meeting of the Society for Promotion of Engineering Education in 1944, there was little doubt left about the requirements. Dean Seaton's frank discussion of the subject clarified the issue and stimulated much constructive thought.

Our chairman, Mr. Fletcher, has sounded the keynote by stating that "accrediting of engineering curricula is a most important step for assuring quality." As engineers and educators, we are vitally interested in the quality of our work and finished product—the graduate. It is true that the quality of instruction varies considerably in the 30 land grant colleges and universities of the United States that offer a professional course in agricultural engineering. Agricultural engineers are concerned about the lack of uniformity in their instruction, and constructive steps are being taken to bring about changes. Our sub-committee on Industry Requirements of Agricultural Engineers has referred to "the chaotic condition existing in schools preparing graduates for the profession." The seven different types of programs reported as existing in this field are of primary concern to this committee. Obviously this is an undesirable situation, but not a hopeless one. A change is taking place that is resulting in improved conditions in all agricultural engineering departments. Such a conference as this one is bringing the issue into the open so that misunderstandings will not prevail.

Now, let us get to the view point of agricultural engineering faculty members on the subject of accrediting curricula. I should say that what follows is largely my own opinion, based on discussions I have participated in, plus accumulated experience in educational work. The majority of us in college work are in favor of the accrediting program and the benefits to be derived from it, yet many agricultural engineering departments must walk or even crawl before they can run. If institutions attempted to meet all the proposed requirements before approving a curriculum in agricultural engineering, there would be very few graduates to be concerned about it. To illustrate, I refer to my own institution, Clemson

College, which launched an agricultural engineering program with one teacher and one extension specialist a generation ago. Today eleven agricultural engineers and several technical assistants are employed in this field. Although we feel that progress is being made in all phases of the agricultural engineering program, we would hesitate to make application to the Engineers' Council for Professional Development for the accrediting of the curriculum. On the other hand, the accrediting program has given us a goal and has probably been the cause of some of the changes that have taken place.

The most difficult requirement to meet for some of the departments is the matter of administering the curriculum. A recent summary of all schools offering a professional course in agricultural engineering shows that in eight institutions the program is administered by schools of engineering. Joint administration by engineering and agricultural schools prevail in nine institutions, and in ten institutions the curriculum is administered by the school of agriculture. We take no pride in this divergency of policy, but there would be little wisdom in eliminating curricula that do not conform in all respects to a proposed standard. There is more logic in improving the existing curricula to the point where, fundamentally, all will have similar characteristics.

Perhaps it is significant that seven departments out of the ten which are administered under the schools of agriculture are located in the South. The South has been referred to as the "problem area" of the United States by a prominent world traveler, and perhaps this is just another example of the problems existing in that area. However, an explanation lies in the fact that agriculture is the principal industry of this area, and it is logical that agricultural interests should be the first to support agricultural engineering. State and National agricultural organizations have been instrumental in bringing about legislation for the support of agricultural engineering activities. This is particularly true of funds for research.

The Engineers' Council for Professional Development has established a precedent by approving a curriculum which is administered jointly by the schools of engineering and agriculture. Under the title, "Why Agricultural Engineers," a brief editorial in the July 1944 issue of the *Agricultural Engineering Journal*, the answer to the question follows: "Broadly speaking, Agricultural Engineering involves the application of the principles of engineering, agriculture, and general science to the problems of agriculture." It is true that agricultural engineers should work closely with agricultural technicians in all fields. Therefore, joint administration of the curriculum would do much to assure this cooperation.

Even though this discussion is centered around the curriculum, a brief comment about research is in order. An agricultural engineering program which is limited to teaching is not likely to be a forceful, progressive one. Teachers should be permitted to do research, and it is usually a simpler task from the standpoint of administration to secure funds for research than for teaching. Obviously the teaching program is strengthened when additional funds become available for the employment of research personnel and for the purchase of equipment and supplies needed in research programs. Agricultural engineering research in

State institutions is financed primarily from Federal and State funds which are administered by the Directors of Agriculture. In many instances, the Director is also Dean of Agriculture, and it is illogical to suppose that full support for research will be afforded if the curriculum is administered entirely by the engineering deans.

The fact that we recognize the weakness of the professional training program is a healthful sign. Because of differences that exist in educational institutions, such as 4 and 5 year plans, we should not expect to completely standardize a program of instruction. We should agree on a curiculum that is flexible enough to conform to institutional and regional standards and requirements.

The agricultural engineering teachers welcome the effort being made to raise the standard of instruction. We want a truly professional curriculum which will merit the approval of E.C.P.D. The full cooperation of all concerned is needed in this effort, and we should ever keep in mind that we are training engineers for service to the agricultural industry.

New Lighting Developments and their Application to Drafting Rooms*

By RUSSELL C. PUTNAM

Associate Professor, Case School of Applied Science

Under the stimulus of war, significant advances have been made in light sources, in lighting equipment, in knowledge of the basic principles of efficient and comfortable seeing, and of the application of all of these to the lighting of drafting rooms. War production, with its long hours of operation, resulted in an increased dependence on artificial lighting. Good lighting installations proved their worth; poor ones soon revealed their weaknesses.

The lessons learned from this wartime experience can be converted to peacetime practices. This reconversion is particularly direct in the case of drafting. The visual tasks and the general conditions are much the same in the industrial and the college drafting rooms. What applies to one is equally applicable to the other.

The four main factors of seeing are generally considered to be: (1) the size of the object; (2) its brightness; (3) the contrast between the object and its immediate surroundings; and (4) the time available for seeing. All of these factors can be improved by more light of the correct quality. The quality and the quantity of the lighting are both important.

The college or university drafting rooms present conditions requiring accurate visual work involving fine discrimination over sustained periods of time; visual requirements which are not exceeded, if indeed equalled, in any other department. Small details must be seen accurately, often under conditions of poor contrast (as when a hard pencil is used on white or manila paper). There are few places where the help of good lighting is needed as much as in the drafting room.

There are few situations also in colleges where the tendency to eyestrain and fatigue is as pronounced. A rather common comment of engineering students is to the effect that they have received definite and sometimes permanent eyestrain in the college drafting rooms and unfortunately, there is all too often some justification of their feeling.

Much has been learned in the last few years concerning the role of good lighting on eye conservation and the reduction of fatigue. Researches and publications of M. Luckiesh, Charles Sheard, R. J. Lythgoe and others in this country and abroad give proof of the effect of lighting and accompanying visual conditions on the consumption of human energy as well as on the ease and comfort of seeing. One quotation from Dr. Charles Sheard, Division of Physics and Biophysical Research, The

* Presented at Joint Meeting, Electrical Engineering and Engineering Drawing Divisions, S.P.E.E. meeting, St. Louis, June 20–23, 1946.

Mayo Foundation, Rochester, Minnesota, may be noted here. In a paper published in the *American Journal of Optometry* in July, 1936, he says, in part, "Even under adequate lighting, with normal vision and adequate reserves of accommodation and convergence, it has been estimated that there is a consumption of a quarter of the bodily energy in the processes of distinct binocular single vision. The ease of seeing, when vision is normal and the powers of accommodation and convergence are adequate, is controlled almost entirely by sufficient and proper lighting. When the lighting is inadequate and improper and when poor vision and ocular insufficiencies are present, the consumption of bodily energy is increased, for various reasons, above the normally necessary amount. For vision which is poor, either because of the need of proper optical assistance or on account of insufficient light, causes uncertainty, tension, annoyance and distraction. These unfavorable reactions and results, produced by increased expenditures of energy, contribute to ocular discomfort and to other trains of symptoms exhibited by abused eyes."

Present recommendations for lighting levels in drafting rooms call for a minimum maintained value of 50 footcandles, with many industrial installations using considerably higher levels. There is rather general recognition that drafting work requires an adequate lighting level, but it is not always appreciated that the quality of lighting must be good also for efficient and comfortable seeing. In the drafting room, there must be a sufficient amount of light with proper distribution, absence of glare and correct brightness control.

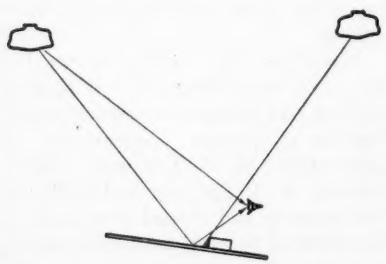


FIG. 1. At or near a horizontal board position, direct and reflected glare may be produced by unshielded lighting units in front of the draftsman. A lighting unit behind the draftsman may cause shadows.

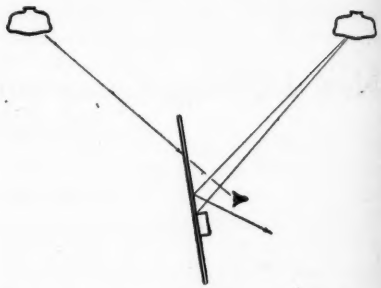


FIG. 2. A more vertical board position reduces shadows and glare.

Proper distribution involves well-diffused light with a minimum of shadows. This question of shadow is particularly important in drafting work as a shadow along the edge of a triangle or T-square may contribute to inaccuracy and be definitely annoying. Indirect lighting systems used with matte white ceilings are effective in reducing shadows, as the ceiling itself acts as a large area, low-brightness light source. The resultant illumination on the drafting table is soft, evenly distributed and of high quality.

At the higher lighting levels, however, the ceiling may get uncomfortably bright with indirect lighting systems, especially in large rooms. This may be helped by the use of ceiling beams to

FIG. 3. High quality lighting on horizontal boards is furnished by this installation of indirect units with silvered-bowl lamps. Beams reduce the amount of ceiling area in the visual field, thus allowing good lighting levels to be reached with comfort in this large room.

FIG. 4. The silvered-bowl incandescent filament lamp equipment in this drafting room combines efficiency, easy maintenance and high quality.

break up the large ceiling area in the visual field, or by the use of semi-direct or direct fluorescent systems.

Although either the incandescent filament or the fluorescent lamp can be used successfully in indirect lighting installations, only the fluorescent lamp has a low enough brightness to be used with semi-direct or direct lighting equipment in a drafting room, and even it should be well shielded so that the lamp itself cannot be seen at ordinary viewing angles. The high efficiency and low radiant heat emission of the fluorescent lamp allow the higher lighting levels to be reached at reasonable consumptions of electrical energy and with physical comfort.

When drafting boards are used in the horizontal position, the shadows under indirect lighting are very soft and almost non-existent, but with direct or semi-direct fluorescent systems, the shadows of straight edges when parallel to the lines of lamps may be annoying. This annoying sharpness of shadows can be reduced by moving either the lamps or the straightedge until they are no longer parallel, but are at an appreciable angle. The feathering out of the shadow edge is noticeable at about a 15° divergence between axes of straightedge and lamps. For ease in installation, however, the lines of fluorescent lighting units are often mounted at a 45° angle to the axis of the board. This is satisfactory in reducing shadows in all positions of T-square and triangle but one—that is, at the 45° angle where the triangle

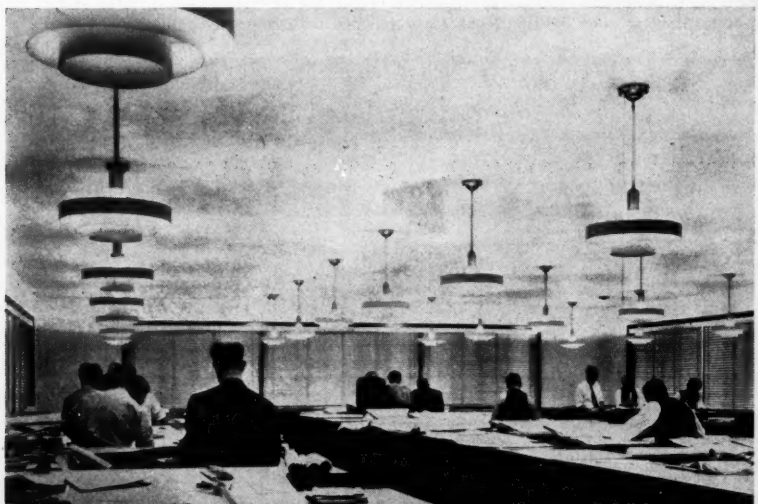


FIG. 5. Indirect incandescent filament units suspended from flat ceilings give excellent quality lighting on horizontal drafting boards in small drafting rooms.

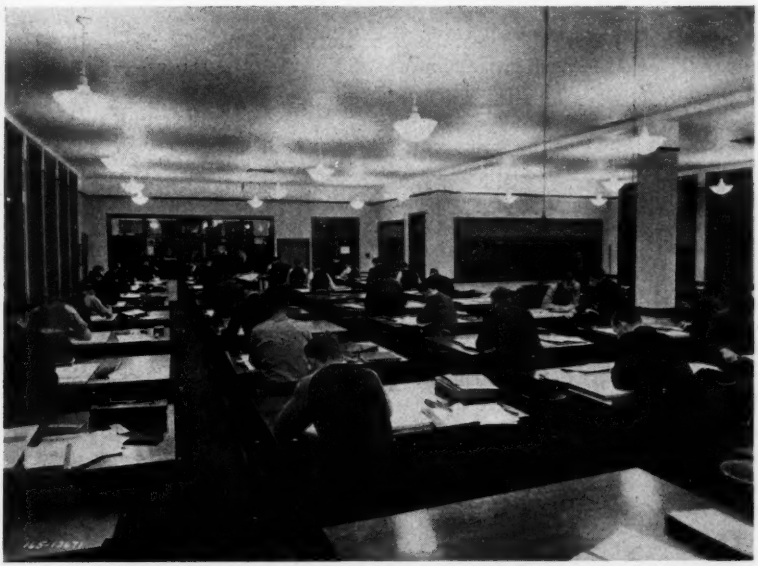


FIG. 6. The standard inside-frost incandescent filament lamp used in plastic or glass luminous-indirect units, as in this drafting room at Case School of Applied Science, gives virtually shadowless lighting with good brightness ratios.

edge is parallel to the lamps. As this position represents but a small fraction of a draftsman's work, the 45° orientation of the lighting units is often used.

Many industrial drafting rooms are using the vertical board with drafting machines. When the board is vertical or nearly so, it is not necessary to use the 45° mounting with direct or semi-direct types of lighting as the angle of the board eliminates the shadows. It also largely eliminates reflected glare as the reflected brightness now is away from the draftsman's eyes and the vertical position also also reduces direct glare by shielding the brightnesses of lighting units and ceiling in front of the draftsman (Fig. 1 and 2).

Glare can be defined as any brightness in the field of view which causes annoyance, discomfort, eye fatigue or interference with vision. It is rather complex, as it depends on the brightness of the glare source, its size, the position in the visual field, the surrounding brightness and the length of time of viewing. Glare can be either direct or reflected and care must be taken to control both. This is especially important in the drafting room because of the specular finishes of triangles and drawing instruments as well as the critical seeing tasks encountered there.

The problems of glare and distribution have been recognized for a long while. The control of brightnesses represents a recent trend, however. In December 1944, the Committee on Standards of Quality and Quantity for Interior Illumination of the Illuminating Engineering Society published a re-

port on brightness ratios which discussed the effect of brightness ratios in the visual field on visibility, comfort and ease of seeing. This report specifies that for good seeing conditions, the brightness of the visual task should not exceed three times that of its immediate surroundings. The same ratios are given for lighting units and their backgrounds although in the latter case practical considerations may increase the limiting ratio to about 10 to 1 due to individual conditions of size and surroundings.

This is an important principle. It affects the type of lighting equipment, and also the finishes of walls, ceiling and floor. In offices and schoolrooms, the finish of the desk tops would be controlled also, but in a drafting room, the work generally covers the top of the drafting table. Reflection factors of 80 per cent or better for ceilings, 50 to 60 per cent for walls, approximately 35 per cent for the trim (around chalkboards, tackboards, windows, etc.) and 35 to 50 per cent for desk tops if they are used, seem to fulfill the specifications of good brightness ratios in a practical manner. All of these finishes should be matte or nearly so; at least they should definitely not be shiny for visual comfort. Color is important from a psychological sense and color preferences vary with different individuals. The illuminating engineer is primarily interested in brightness and the resultant brightness ratios in the field of view and does not care particularly what color is chosen as long

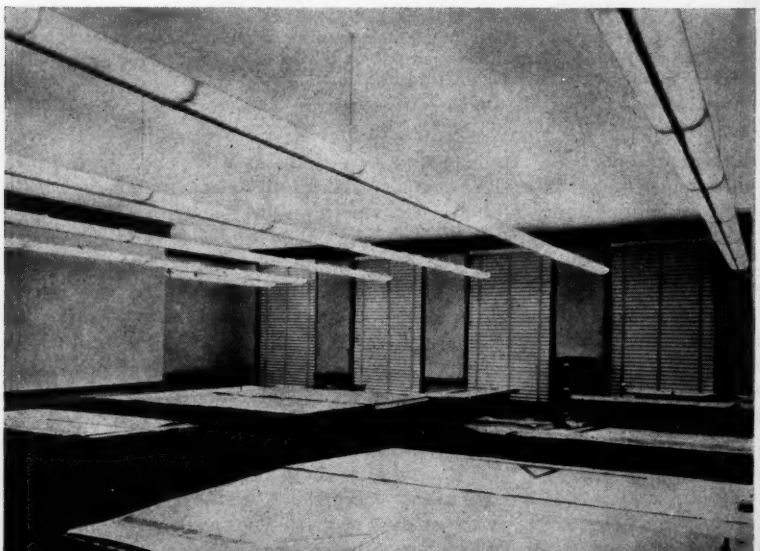


FIG. 7. Luminous-indirect fluorescent systems combine the quality of indirect lighting with the high efficiency of the fluorescent lamp.

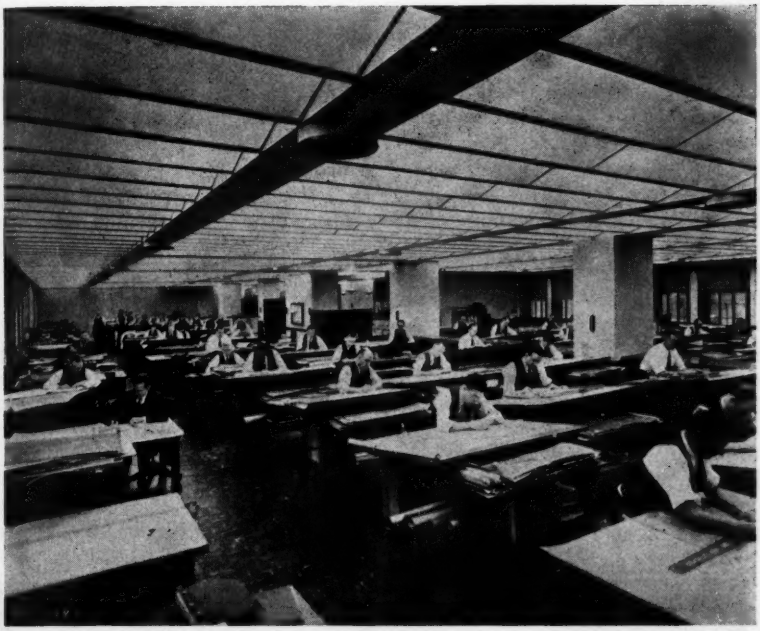


FIG. 8. Fluorescent lamps mounted behind glass panels create a virtual artificial skylight in this large industrial drafting room. The angle of the glass plates reduces the ceiling brightness as observed by the draftsman.

as it meets the reflection factor specifications.

Progress has been made in light sources and in lighting equipment as well as in the principles of efficient and comfortable seeing.

The virtually shadowless quality of lighting that results from an overcast sky can be duplicated by indirect or luminous-indirect lighting units and a matte white ceiling. Figure 3 is an illustration of an industrial drafting room which uses silvered-bowl lamps in indirect units to give a lighting level of approximately 45 footcandles on the drafting boards. A variation of indirect lighting with the silvered-bowl incandescent filament lamp utilizes silvered-bowl lamps in a very efficient luminaire made of three concentric rings to shield the bright upper part of the bulb, the silvered-bowl of the lamp being the reflecting surface (Fig. 4). The use of beams to reduce the amount of ceiling area in the visual field permits a good lighting level of excellent quality and comfortable brightness conditions in large rooms. For smaller drafting rooms where the cumulative effect of the ceiling is not as pronounced, the indirect units suspended from a flat ceiling (Fig. 5) give an excellent combination of high efficiency incandescent filament lighting and good quality. Two of the advantages of the silvered-

bowl lamp are the ease with which it is kept clean and the fact that a new reflecting surface is automatically provided every time a lamp is replaced.

The standard inside-frost filament lamp can also give excellent results for drafting when used in a plastic or glass luminous-indirect unit (Fig. 6). These units do collect dirt, but they are translucent enough so that the presence of dirt and other extraneous objects shows from below and gives an unmistakable indication of when they should be cleaned. The brightness ratio of this type of lighting unit with the ceiling is also good.

With indirect systems, the reflection factor of the ceiling must be kept high in addition to keeping the lighting equipment clean, as the ceiling is the secondary light source. The ceiling darkens slowly and may possibly not be noticed until there has been a severe decrease in lighting level. A yearly cleaning schedule with refinishing when necessary, will prevent the deterioration of ceiling reflection factors that is all too prevalent.

With the development of the highly efficient fluorescent lamp, it was natural that this new lamp should be applied to drafting room lighting in a similar way to that found good for the incandescent filament lamp; that is, in indirect or luminous-indirect lighting equipment. The industrial drafting room shown in Fig. 7 is an excellent illustration of luminous-indirect fluorescent lighting of high quality.

As the appearance and the quality of the artificial lighting systems approximated skylight conditions, it was

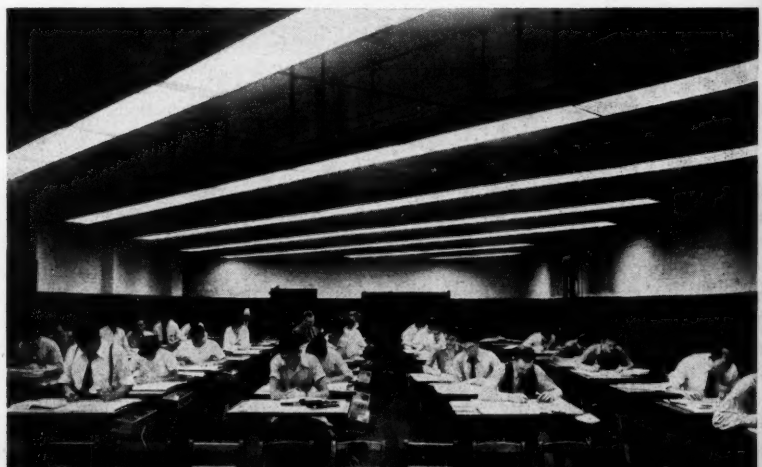


FIG. 9. Louvered fluorescent units in continuous rows with 45° mounting tripled the lighting level for the same connected wattage in this converted drafting room at Case School of Applied Science.

FIG. 10. Ceiling mounted, louvered, fluorescent troffers in continuous rows at 45 degrees to the axis of the work give efficient quality lighting at high lighting levels in this industrial drafting room.

a natural step to design fluorescent lighting installations for drafting rooms that were virtually skylights with fluorescent lamps above the glass. Such an installation is shown in Fig. 8 where an almost complete ceiling of glass acts as a diffusing medium for the fluorescent lamps which are mounted behind the glass plates.

Advantage can be taken of the comparatively low brightness of the fluorescent lamp to design equipment with higher efficiency and easier maintenance than the previous examples. Although the brightness of this lamp is higher than one would care to have in the normal field of view for prolonged periods, it is judged to be tolerable from the standpoint of reflected glare for the majority of drafting room uses if the lighting level is 50 footcandles or more and the lamps are distributed over the ceiling. This has led to the design of semi-direct and direct units which have proved very satisfactory when used in accordance with the principles of efficient and comfortable seeing.

Since direct and semi-direct luminaires do not shield the lamp from the work, although they do shield the lamp from the eyes of the draftsman, the question of the best angle between the lamp and drawing board for greatest reduction of shadows is important. Research and trial led to the selection of 45 degrees as the most practical solution of the problem as mentioned previously. One of the very first such

installations (probably the first in an educational institution) was made at the Case School of Applied Science before the war (Fig. 9). Here, in a drafting room on the top floor of an old building, the lighting level was raised from an average of 14 footcandles with the old filament indirect units to about 50 footcandles maintained with approximately the same total wattage in both cases. These continuous rows of units are equipped with louvers to shield the lamps from the eyes of the students. Somewhat similar installations in industrial drafting rooms also utilize the 45° mounting at lighting levels ranging from 60 to 100 footcandles(Fig. 10). In the later installations, the lighting units are so designed that some light is spread over the ceiling as well as on the work in order to keep the brightness ratios comfortable.

In new construction, a trend in present practice is to the use of fluorescent lamps in recessed troffers, generally used with an acoustical ceiling. Now that aluminum has become available, the most comfortable conditions result from troffers which use lightly etched aluminum as the reflecting surface. Since the trend in industry seems also to be to the vertical drafting board, a combination of recessed troffers and vertical boards (Fig. 11), may be considered as typical of the best present practice.

The need for relighting drafting

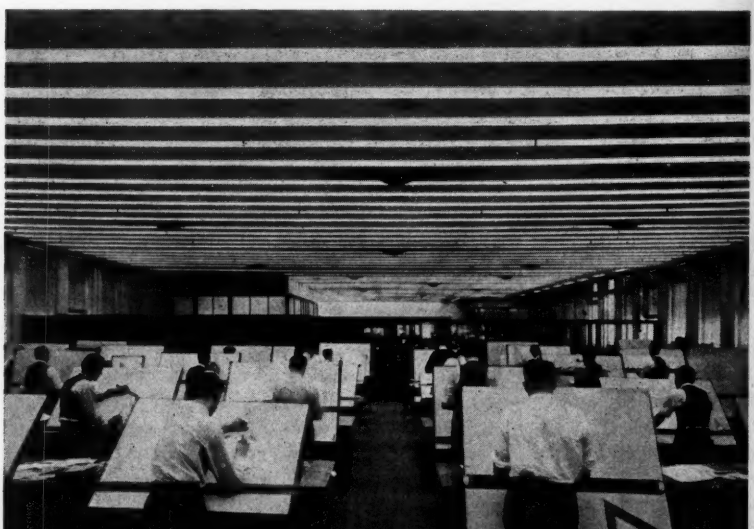


FIG. 11. The combination of diffuse aluminum recessed fluorescent troffers, acoustical ceiling, and approximately vertical drafting boards, is typical of good present practice with fluorescent lamps.

FIG. 12. This semi-direct unit, aluminum finished, with two 40-watt fluorescent lamps per 4′ length, is typical of some of the newest developments suitable for both new and relighting application. Shown here in a grade school classroom, such installations are equally applicable to drafting rooms.

rooms in colleges and universities is much more pressing than the lighting of new buildings. Professors have been conscious of the advances in drafting room lighting in industry; many of them have worked under some of the new installations. They are interested in the possibility of replacing their present inadequate lighting systems. What is the answer to their problem?

Local conditions may influence the choice of equipment, but in the great majority of cases, the choice will rest between an indirect system (filament or fluorescent) or a semi-direct system (fluorescent). Several of the installations which have been discussed are relighting projects which have taken the place of less satisfactory equipment. Some new fluorescent designs have recently been announced which are excellent for light control, efficiency and maintenance. Some of these are so new that the first installations are just being made and pictures are not yet available. An installation in a classroom of the Oxford School, Cleveland Heights, Ohio (Fig. 12), gives a maintained lighting level of nearly 50 footcandles with efficiency, good maintenance and comfort. This is typical of some of the newest developments which are equally applicable to drafting rooms.

Tracing presents a difficult lighting problem, especially where the visibility

of the original is low. A trans-illuminated tracing table which projects light through the original, silhouetting the lines on the drawing, makes the job of tracing a great deal easier (Fig. 13). The use of such tracing tables was retarded for many years by the difficulty of using thumb tacks and by the problem of heat from the filament lamps. Now the availability of easily removable adhesive tape makes it possible to work on even the smallest drawing at any convenient location on the transmitting glass surface, while the fluorescent lamp supplies adequate light with relatively little heating. These also can be tilted toward the vertical if desired, since the use of the fluorescent lamp permits compact construction.

In fluorescent lamps and control, there are also interesting recent advances. A new color has been added; in addition to the standard 3500° white lamp and the daylight lamp, there is now available a 4500° white lamp which is midway in color quality between the two and incorporates many of the advantages of each. Fluorescent lamps may also be started instantly if desired, without the slight delay of the standard pre-heat start.

A very new lamp—so new that the

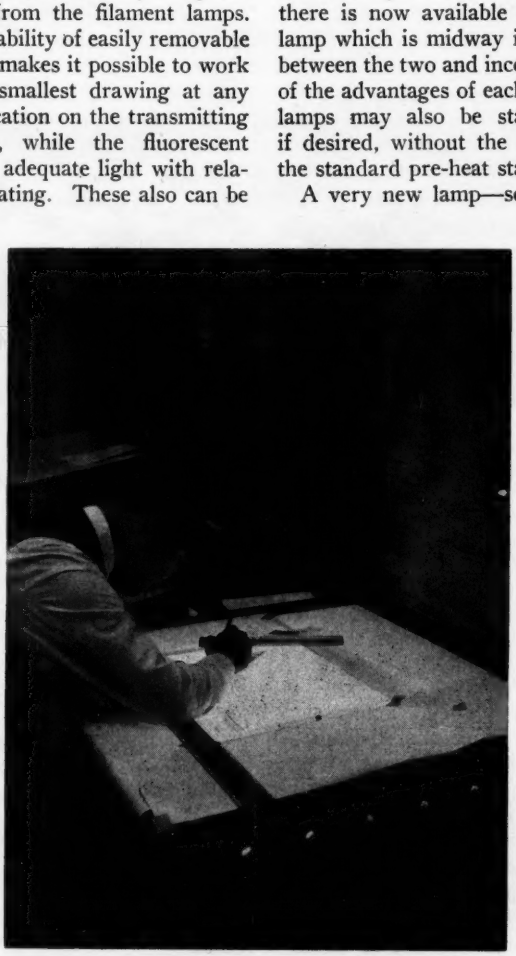


FIG. 13. Tracing is greatly facilitated by a trans-illuminated tracing table using fluorescent lamps.

first installations are just now being made—offers great promise for drafting room work in connection with recessed troffers or semi-direct equipment. It is the low-brightness 40-watt fluorescent lamp, which has twice the area and hence approximately half the brightness of the standard 40-watt lamp, thus reducing reflected glare. It is furnished for instant starting and it is made in the new 4500° color.

Good drafting room lighting can be obtained from either filament or fluorescent lamps, if used intelligently. Very uncomfortable, annoying and unsatisfactory installations can result from either light source also if the rules of good lighting and seeing are not followed. Competent engineering advice should be secured as the exacting visual tasks and close application over long periods of time required in drafting make the highest quality lighting a necessity. The trend definitely is to fluorescent lamps for drafting room installations because of their high efficiency and low radiant heat emission, but whatever light source is used, care should be taken that the installation incorporates the accumulated knowledge of what constitutes good seeing and good lighting practice. Electrical engineering, through its sub-division of illuminating engineering, is in a position to make significant and valuable contributions to engineering drawing through recent advances in basic knowledge and in lighting technique.

Admission Test Procedure*

By R. R. SLAYMAKER

Dean of Junior Division and Professor of Machine Design, Case School of Applied Science

The success which we have had at Case School of Applied Science with the Pre-Engineering Inventory† in conjunction with a professional interest test has led us to the adoption of the Pre-Engineering Inventory as an entrance examination.‡ After admission the data from the professional interest test, the PEI and the American Council on Education Psychological Examination are used in guiding the student into the course of study most suited to him.

This paper is a report of our findings showing how the entrance and guidance battery was selected and giving some of our conclusions after using it for three terms.

Selection of a Test Battery

Case School has been giving objective type tests to entering freshmen since the days of World War I. The tests were used for selective sectioning and also to determine whether or not the student would succeed in the Case curriculum. There was little opportunity, however, to find out where his aptitudes and interests lay if he were not a Case man and the tests were never used as entrance examinations for all applicants.

In November 1944 a study of the various placement tests used at Case was undertaken in an effort to select a battery which would serve two purposes, (1) to predict most accurately the performance of freshmen and thus serve as entrance examinations, and (2) to furnish the most reliable information for guidance purposes. Members of the class entering in November 1944 served as guinea pigs for these men were given subject matter, training, and aptitude tests, the Pre-Engineering Inventory and a general learning ability test as well as tests of personality and professional interest. Without going into too much detail it is sufficient to say that the Pre-Engineering Inventory proved to be the best not only as a means of predicting success but also as a measure of the student's various mental capacities. The Kuder Preference record § seemed to furnish the most information about his professional interest.

* Presented at 54th annual meeting, S.P.E.E., St. Louis, June 20–23, 1946.

† A battery of seven tests developed by the Measurement and Guidance Project in Engineering Education under the directorship of Dr. K. W. Vaughn. Journal of Engineering Education, Vol. 35, No. 3, pp. 161–179, Nov., 1944; Journal of Engineering Education, Vol. 34, No. 9, pp. 615–625, May, 1944; Journal of Engineering Education, Vol. 34, No. 7, pp. 516–520, Mar., 1944.

‡ This examination is a part of the procedure. Other items considered are high school academic record, high school student activity record, choice of curriculum and personal recommendations.

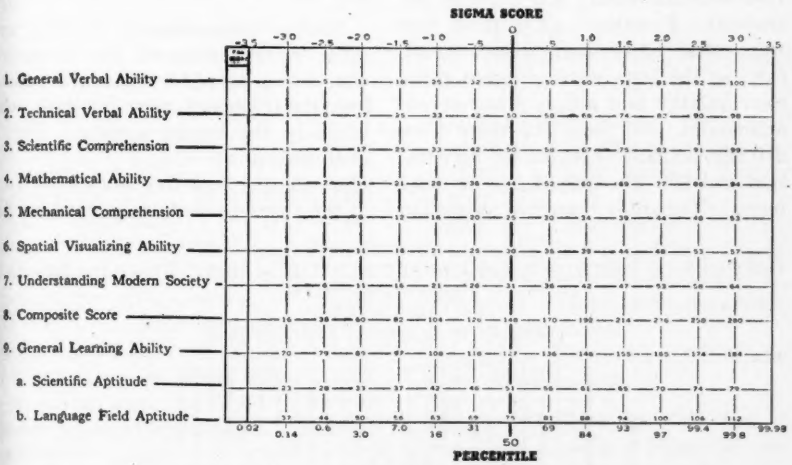
§ A professional interest test prepared by G. Frederic Kuder and published by Science Research Associates.

The student's scores are recorded on the Guidance Report Form shown in Fig. 1. The form is self-explanatory and can be readily understood by the students.

The first seven tests are the Pre-Engineering Inventory. Item 8 is the PEI composite score made up of Tests 2, 3, and 4, and is the score which is most indicative of success in freshman

CASE SCHOOL OF APPLIED SCIENCE
GUIDANCE REPORT FORM

Name_____ Date_____



The profile appearing above represents your score on the guidance examinations given at Case School of Applied Science. The "Zero" line on the sigma scale at top of the chart represents the score achieved by the average Case applicant. Scores above average are shown to the right of the "Zero" line and scores below average are shown to the left. The scale indicates the degree above or below average.

Your percentile rank in any of the tests may be found by reading the scale at the bottom of the chart. For example, if your percentile rank in test 6 were 84 you surpass 84% of the Case students in Spatial Visualizing Ability.

Applicants whose profile points fall near zero on items 1, 2, 3, 4, 8 and 9 and particularly on items 8 and 9a, if they enter Case, should keep in touch with advisors during the first two terms of study.

Those applicants whose profile points fall much below zero would do well to consult with educational advisors at Case or other schools before selecting the type of college course they wish to pursue.

1. Mechanical.....
2. Computational.....
3. Scientific.....
4. Persuasive.....
5. Artistic.....
6. Literary.....
7. Musical.....
8. Social Service.....
9. Clerical.....

INTERESTS

The interest scores are based on a scale of 1 to 100. The ratings you receive indicate your interest in the various fields of work indicated at the left. A score of 80 or above indicates strong interest in the type of work found in the field. Low scores indicate that you dislike work of the nature indicated at the left. Students who find that they like the work involved in an engineering and physical science school usually score high in 3 and 2, moderately high in 1 with no other high scores other than 4 which occurs when they have sales engineering interests, or 5 when interested in architectural engineering. Those whose interest pattern is low in 3, 2, and 1 and whose aptitudinal profile is low in the factors mentioned above should consult with educational advisors during the first two terms

FIG. 1.

level engineering courses. Item 9 is the American Council on Education total score. The ACE Q score is shown as Item 9a and the L score as 9b.

Professional interest is shown under the nine classifications of the Kuder Preference Record at the bottom of the report form.

During the three terms beginning November 1944, March 1945, and July 1945 this test battery was given to 307 students. Practically all of these men were admitted on high school certificate, so the tests were given to study their validity and not as entrance examinations. Of these 307 there were 210 who actually appeared for registration and 198 who stayed one or more terms. The study therefore consists of 198 cases who remained in school long enough to get a point average.

We found that the PEI composite score alone formed a basis for prediction which was much superior to the widely used ACE but that combining the two scores formed a better basis. The most satisfactory prediction score for us seems to be

5(PEI composite Z score)
+ (ACE Total Z score).

Such a combination of the PEI and ACE scores separated the frequency distribution curve for those who passed from the frequency curve for those who failed by the largest amount. Fig. 2 illustrates this.

Here the per cent frequency (per cent of the cases studied) is plotted on the

FREQUENCY DISTRIBUTION ON PREDICTION SCORE* OF FAILURE AND PASSING GROUPS
198 CASES
RANGE OF SCORES—14.00 TO 18.50

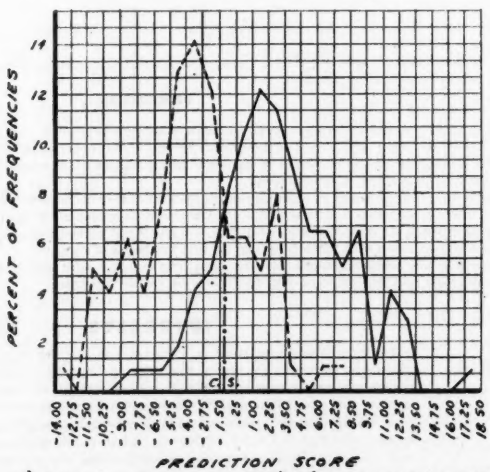


FIG. 2

y axis and the corresponding prediction score on the x axis. The dotted curve shows the distribution of prediction scores for the students who were unsuccessful at Case and the solid curve shows the distribution of those who succeeded. The criterion for success is considered to be a 0.7 point average, above 0.7 being satisfactory and below 0.7 unsatisfactory.

Point values are assigned as follows.

A = + 3
B = + 2
C = + 1
D = 0
Incomplete = − 1
Failure = − 2

The curves show, for example, that slightly more than 14 per cent of the men who failed received a prediction score between − 2.75 and − 4.00 and that a little more than 12 per cent of the men who passed received a prediction score between + 1.00 and + 2.25. Notice that no one passed who received a prediction score less than − 9.00 and no one failed who received a prediction score above + 8.50.

The intersection of these two curves is, of course, the critical score which for ease of analysis was set at − 1.50. When we began using this battery of tests as entrance examinations it was decided to classify as definitely acceptable those whose prediction scores were above + 3.50 and to reject definitely those whose scores were less than the critical of − 1.50. Between − 1.50 and + 3.5 are the doubtful cases.

Classification of Students According to Prediction Score

The information in Fig. 2 is shown more vividly in Fig. 3. Here, the test score and the corresponding point average is plotted for each individual student. For example, notice in the lower left hand corner of the chart that there was one man who received a test score between − 12.75 and − 14.00 who had a point average at the end of the term between − 1.5 and − 1.7. Observe about the middle of the chart that there were 5 men who received a test score betwen 1.00 and 2.25 who had a point average at the end of the term between 1.1 and 1.3.

The freshman class, therefore, is divided into the customary four groups on the chart.

Group I. Those above the critical score of − 1.5 who passed, *i.e.*, received a point average greater than 0.7.

Group II. Those below the critical score of − 1.5 who failed, *i.e.*, received a point average below 0.7.

Group III. Those above the critical score who failed.

Group IV. Those below the critical score who passed.

Notice that there are 107 men in Group I and 52 men in Group II, and that the men in these two groups comprise 159/198 or 80 per cent of the total. In other words, considering the test score alone, it is possible to predict a man's performance in 80 per cent of the cases.

Had these men been screened by not admitting those with a score less than − 1.50, we would seemingly have done an injustice to 16 of the 198. As a matter of fact, however, 10 of the 16 failed at the end of the second term, so that we would have unjustly excluded only 6 men.

Aptitude and Interest Patterns

At the risk of being accused of overanalyzing statistics we next investi-

SCATTERGRAM DEPICTING RELATIONSHIP BETWEEN THE PREDICTION SCORE AND THE QUALITY POINT AVERAGE
198 CASES

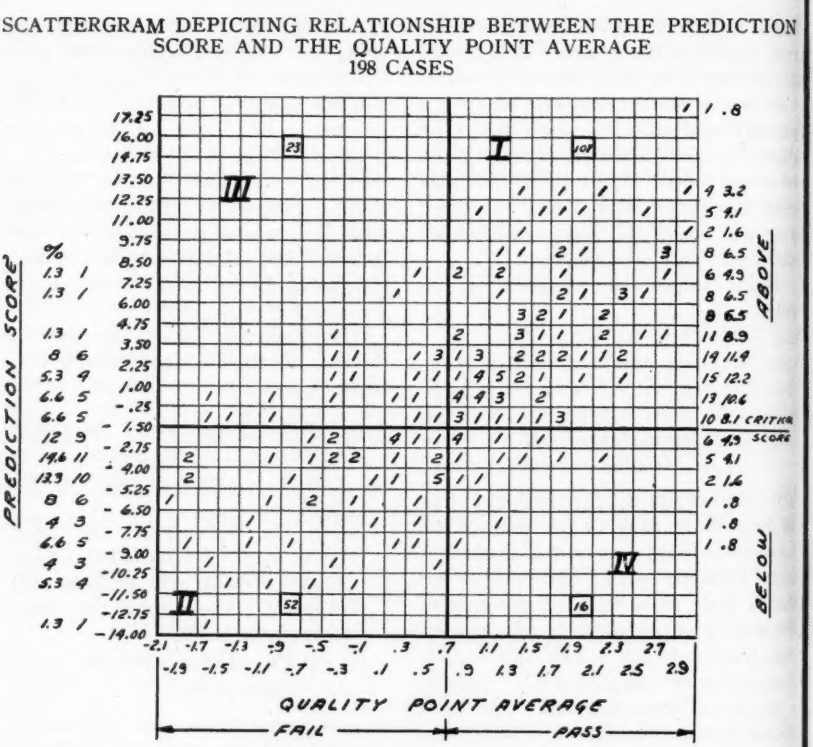


FIG. 3.

210 APPLICANTS APPEARED FOR MATRICULATION. 12 LEFT SCHOOL BEFORE THE END OF THE TERM. EXAMINATION OF THE SCATTERGRAM WILL INDICATE, QUITE CLEARLY, THE DIFFERENTIATION BETWEEN THE FAILING AND PASSING GROUPS.

gated the 23 men in Group III, those above the critical score who failed.

To see whether there was any noticeable difference in the test profiles of the men in Group III as compared with the men in Group I we selected two individuals with the same range of prediction score but whose point averages at the end of the term were widely different. Figure 4 shows the comparison.

Both men scored in the vicinity of 0.5 on the sigma scale for Item 8 yet student A, who carried a full load during the first term, received a point average of 1.25 and student B, who carried a light load, received a point average of 0.58. Student B possesses certain abilities which Student A does not, but evidently his peak abilities are not those needed in an engineering and scientific school.

Further examination showed that this same general difference in pattern existed for most of the men in these two groups. Therefore we averaged

the scores to get a composite Group I man and a composite Group III man and plotted the result in Fig. 5.

Notice that the average Group III man has more general verbal ability than the average man in Group I. He has also a greater understanding of modern society and a greater language field aptitude. However, he is below the man who succeeded at Case in technical verbal ability, mathematical ability, spatial visualization, comprehension of scientific and mechanical principles and scientific aptitude. Both of these groups have the same general learning ability as measured by the total score of the ACE.

The interests of these two groups show a similar characteristic difference. The Group I man is much more interested in computational and scientific matters than the average man in Group III. The Group III man, on the contrary, has more of a literary interest and far surpasses his Group I brother in being interested in the persuasive type of profession. In other words, he has more in common with the personnel manager, the sales engineer, the politician, and the diplomat than he has with the research scientist, the stress analyst, or the inventor.

Although it can be argued that this study includes a relatively small sample and therefore is not too conclusive, the trends cannot be ignored. We feel that we are safe in saying that men having a characteristic test profile similar to Group III, while they are capable enough generally, would be much happier in a more liberal type of program than the rigorously scientific one open to them at Case. The method of finding these men and directing them into a course of study suitable to their needs will be discussed later.

A fairly complete group mean analy-

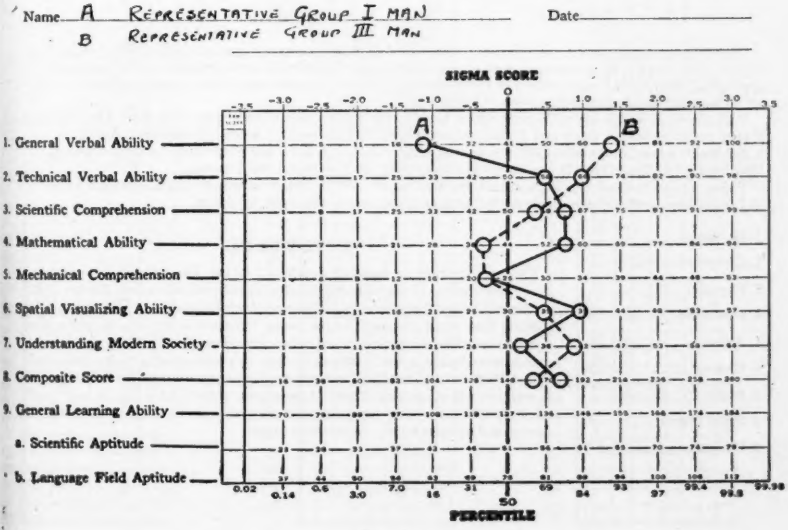
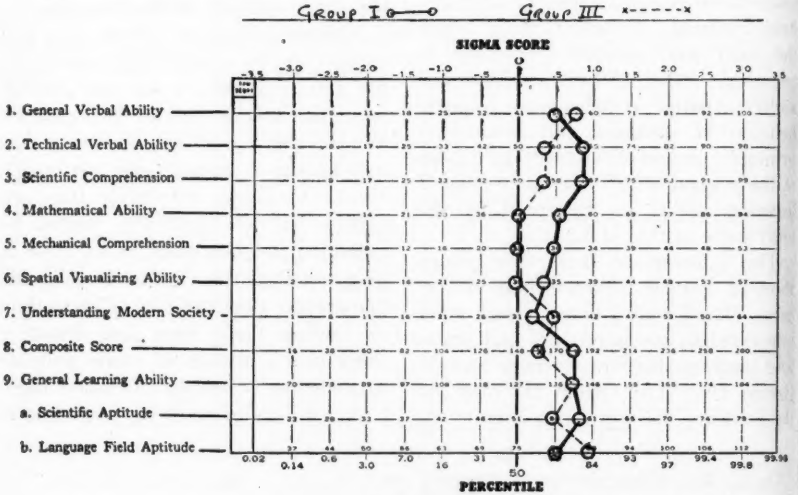


FIG. 4.

COMPARISON OF CAPACITIES OF GROUP I AND GROUP III STUDENTS
GROUP I, ABOVE C.S. WHO PASSED. GROUP III, ABOVE C.S. WHO FAILED.

CASE SCHOOL OF APPLIED SCIENCE
GUIDANCE REPORT FORM

Name_____ Date_____


Group I o—o
Group III x- - - - -x
SIGMA SCORE
-3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -.5 0 .5 1.0 1.5 2.0 2.5 3.0 3.5
1. General Verbal Ability
2. Technical Verbal Ability
3. Scientific Comprehension
4. Mathematical Ability
5. Mechanical Comprehension
6. Spatial Visualizing Ability
7. Understanding Modern Society
8. Composite Score
9. General Learning Ability
a. Scientific Aptitude
b. Language Field Aptitude
0.02 0.14 0.6 3.0 7.0 16 31 50 84 93 97 99.4 99.8
PERCENTILE

The profile appearing above represents your score on the guidance examinations given at Case School of Applied Science. The "Zero" line on the sigma scale at top of the chart represents the score achieved by the average Case applicant. Scores above average are shown to the right of the "Zero" line and scores below average are shown to the left. The scale indicates the degree above or below average.

Your percentile rank in any of the tests may be found by reading the scale at the bottom of the chart. For example, if your percentile rank in test 6 were 84 you surpass 84% of the Case students in Spatial Visualizing Ability.

Applicants whose profile points fall near zero on items 1, 2, 3, 4, 8 and 9 and particularly on items 8 and 9a, if they enter Case, should keep in touch with advisors during the first two terms of study.

Those applicants whose profile points fall much below zero would do well to consult with educational advisors at Case or other schools before selecting the type of college course they wish to pursue.

	I	III
1. Mechanical	75	72
2. Computational	78	56
3. Scientific	82	61
4. Persuasive	43	82
5. Artistic	55	54
6. Literary	52	65
7. Musical	46	55
8. Social Service	35	45
9. Clerical	37	30

INTERESTS

The interest scores are based on a scale of 1 to 100. The ratings you receive indicate your interest in the various fields of work indicated at the left. A score of 80 or above indicates strong interest in the type of work found in the field. Low scores indicate that you dislike work of the nature indicated at the left. Students who find that they like the work involved in an engineering and physical science school usually score high in 3 and 2, moderately high in 1 with no other high scores other than 4 which occurs when they have sales engineering interests, or 5 when interested in architectural engineering. Those whose interest pattern is low in 3, 2, and 1 and whose aptitudinal profile is low in the factors mentioned above should consult with educational advisors during the first two terms.

FIG. 5.

sis of professional interest is shown in Fig. 6.

The characteristic differences of the men in Group I and Group III which have already been discussed can be seen more clearly here.

It might be inferred by studying the Group IV interest chart that the men in this group succeeded because they were intensely interested in their work. However, the Group II men, below the critical who failed, were also reason-

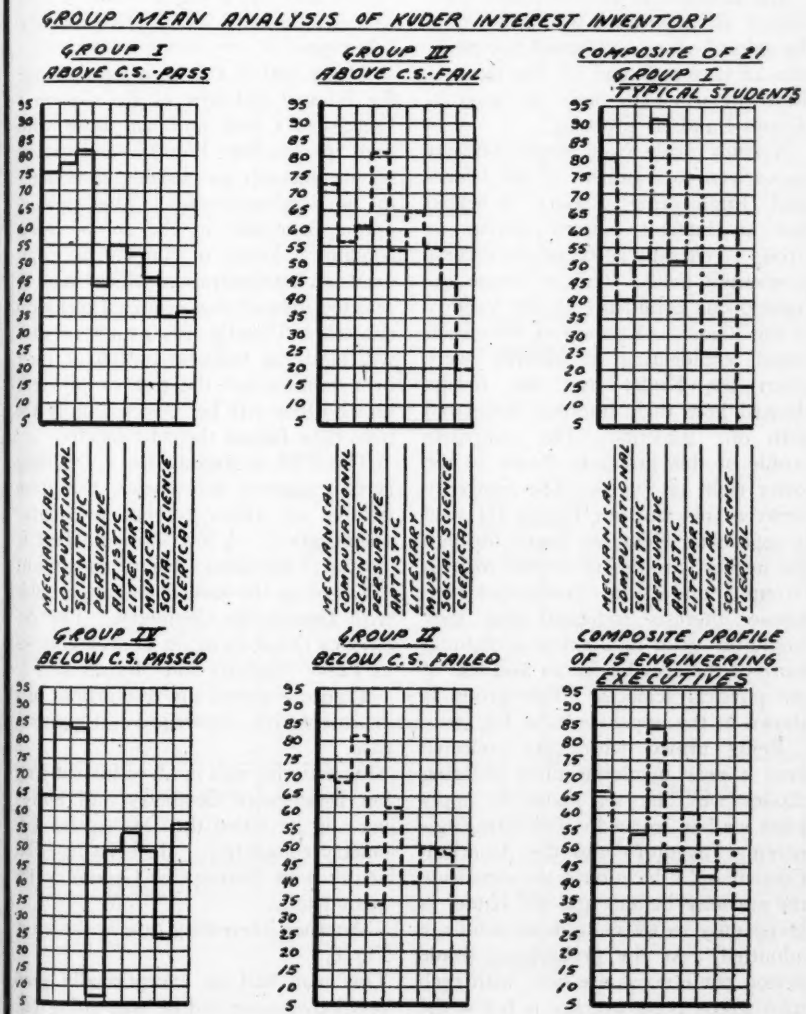


FIG. 6.

ably interested in things scientific and disinterested in the persuasive type of profession. The Group II men failed simply because of lack of ability.

Guidance Features

The decision to exclude from Case School all applicants who fell below the critical score eliminated the problems of Group II and IV but made it more important to place the men in Groups I and III properly.

A study made from Kuder interest tests given to members of the Cleveland Engineering Society indicated that an interest pattern similar to Group I generally accompanies success in scientific fields. This, of course, increased our confidence in the validity of the Kuder. A group of fifteen selected engineering executives were given the Kuder and the results showed how their interests compared with our students. The composite profile of this group is shown in the lower right of Fig. 6. The similarity between this and our Group III men is apparent. Next, we paged through the interest profiles of all the men in Group I and found twenty-one men whose interests indicated that they would do better in a course containing more of the social sciences and less of the physical sciences. This group is shown in the upper right of Fig. 6.

Being armed with data collected over a year involving three entering classes we then set about to apply what we had learned. The Pre-Engineering Inventory and the American Council on Education tests constitute the entrance battery and the Kuder is given only to those students who are admitted. At the preliminary grade period conferences are held with each man whose point average is below the required ⅔. We discuss the information found on his guidance report in detail and if his peak aptitudes and interests are not those of the successful scientific school man he may be advised to change his training objective before the term is over. Such a procedure cuts down the number of men who end the term with a point average below par.

At the end of the term we examine the interest patterns of the Group I (successful) men and list those with high persuasive, literary and social service inerests as possible candidates for our business option. The business option, available in the senior year, contains a group of courses in Engineering Administration which may be selected instead of specialized technical subjects. Usually this group of men will elect the business option of their own volition and the test simply tells us who they will be. Occasionally the tests have helped them to decide.

The PEI is useful also in spotting certain natural deficiencies, the most notable of which is that of spatial visualization. A low score in Test 6, Spatial Visualizing Ability, is usually followed by the student having trouble with Descriptive Geometry. The deficiency crops up again in such courses as Force Analysis and Mechanism.

Figure 7 shows the test profile of a representative Descriptive Geometry case.
This man did well in all of his subjects but Descriptive Geometry and Drawing and he failed the Descriptive Geometry completely. He even had difficulty with Descriptive Geometry the second time.

Another interesting case is shown in Fig. 8.
This man had an exceptionally good predictive score and he was doing better than C work at mid term so he was

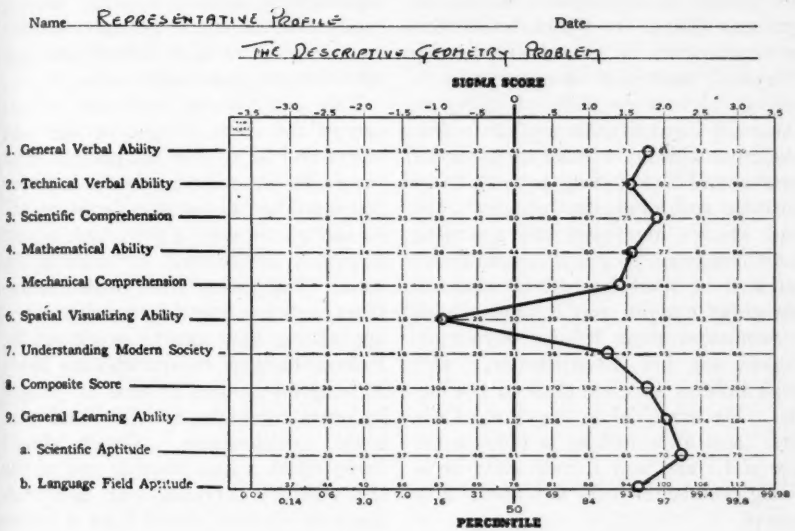

Name REPRESENTATIVE PROFILE
Date
THE DESCRIPTIVE GEOMETRY PROBLEM
SIGMA SCORE
1. General Verbal Ability
2. Technical Verbal Ability
3. Scientific Comprehension
4. Mathematical Ability
5. Mechanical Comprehension
6. Spatial Visualizing Ability
7. Understanding Modern Society
8. Composite Score
9. General Learning Ability
a. Scientific Aptitude
b. Language Field Aptitude
PERCENTILE

FIG. 7.

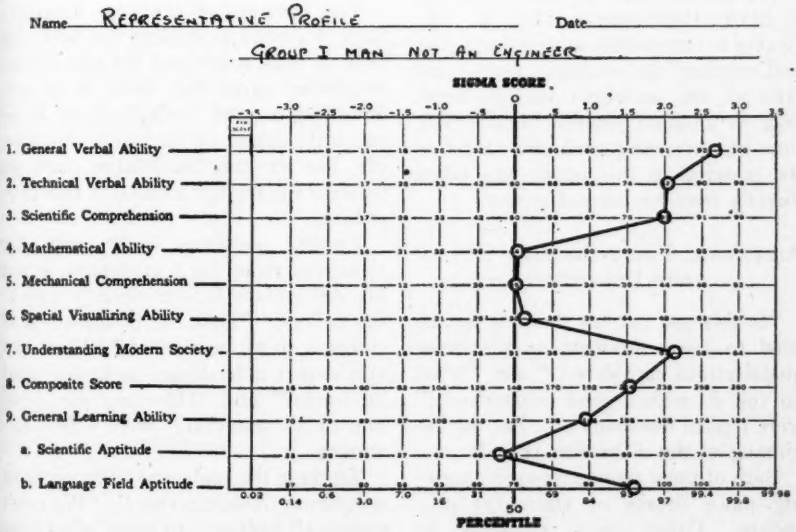

Name REPRESENTATIVE PROFILE
Date
GROUP I MAN NOT AN ENGINEER
SIGMA SCORE
1. General Verbal Ability
2. Technical Verbal Ability
3. Scientific Comprehension
4. Mathematical Ability
5. Mechanical Comprehension
6. Spatial Visualizing Ability
7. Understanding Modern Society
8. Composite Score
9. General Learning Ability
a. Scientific Aptitude
b. Language Field Aptitude
PERCENTILE

FIG. 8.

not brought to my attention because of grades. About six weeks before the term was over, he came in and said, "Dean, I can't take it, something is wrong. I hate to think of going to classes. I'm nervous and on edge. I'm cross with my wife for no apparent reason and I'm getting to be a very irritable and unpleasant person." He had always impressed me as being most congenial, so I was especially interested in what he had to say. A glance at his test profile and a little conversation about it soon gave us a reason for his dissatisfaction. His peak abilities were not those of a scientist. He left Case at the close of his first term after making a point average of 1.5 and now I understand he is doing even better work in a liberal arts school.

Acknowledgment

We are fortunate at Case in having a Staff Psychologist. Dr. C. W. Graves is responsible for administering and scoring the entrance tests. He does all the statistical analysis work and, in addition, spends considerable time in counseling students. Most of the material in this paper was taken directly from his annual report.

Additional Facts Brought Out in the Discussion

"Is this test battery the only means used to select students or are other qualifications considered?" and "What do you do with a good quarterback?" were typical questions asked at the beginning of the discussion period.

Both of these were answered by giving more details of admission procedure. Other items considered in addition to the test scores are as follows: high school academic record, high school student activity record, choice of curriculum, personal recommendation from high school and our interviewer's personality rating.

The high school academic record carries the same weight as the test scores and because of the present tidal wave of students both must be high for the candidate to be considered at all. In fact a man with a poor high school record is advised not to attempt the tests. The group from which selections are made has a better than average chance for success academically. From it men are chosen who are likely to be good campus citizens as judged by extra curricular activities and personal qualifications. Other things being equal, a man electing one of the less crowded curricula such as metallurgy or physics would have a better chance of finding a place in the freshman class than one wishing to study mechanical or electrical engineering.

The question of the good quarterback is always a problem but both the athletic department and the admissions committee agree that there is no use admitting a good football player if he has little chance of remaining eligible. He, like all other candidates, must go through the regular admission test procedure.

Further questions dealth with the system of requiring a student to select his curriculum before actually entering college. "Isn't the freshman year common to all curricula?," "How can you expect a freshman to know what he wants?" and "How can you hold him to his selection?" were a few examples.

To these the reply was "We do have a common freshman year." "We can't expect all freshmen to know what they want." "We do not turn a man out of school because he changes his mind."

But the system does balance the loads in the various departments and here is how it works.

At an assembly preceding the admission tests the men are told about the capacities of the various degree granting departments and are then asked to record their first, second and third choices. Usually when the final selections are made the men get their first choice but we try never to refuse a good man if he can be placed in a less crowded department.

If toward the close of the freshman year a man decides to study for a degree different from the one to which he committed himself on admission, he files a petition with the Committee on Student Personnel. All such petitions are held until the second semester is finished and then acted upon at once. But this time there are usually enough paired exchanges to keep the number of students in each curriculum at the previously estimated level. So far the system has worked very smoothly. The department loads have been kept fairly constant and no student has been disappointed in his choice of a curriculum.

A Five-Year Mechanical Engineering Curriculum

By R. C. JORDAN

Professor and Assistant Head, Mechanical Engineering Department, University of Minnesota

The Mechanical Engineering Department, along with the other divisions of the Institute of Technology at the University of Minnesota, is adopting a five-year curriculum for all entering students other than veterans of World War II. Although practically all of the fifth year of additional work will be in the humanistic-social area and distributed throughout the five-year curriculum, several other basic changes in the engineering area have also been included. All students successfully completing this five-year curriculum will receive the B.M.E. degree. In addition all students with a 1.8 honor point average or higher will receive a B.S. degree undesignated, and through petition this degree may be granted to these students at the end of their fourth year.

The entire program proposes not only to train the student engineer in those sciences basic to engineering and to develop in him an understanding of engineering methods and practices, but also to increase his ability to analyze critically the relationships and effects of his own engineering field upon the social and economic framework in which he is required to operate and live. In order that, as an engineer, he may function most effectively, it is necessary that he possess a sound professional attitude and training, well-developed moral, social and economic concepts, and the ability to express his ideas clearly in both written and oral English. These aims are essentially those which have been presented through the JOURNAL OF ENGINEERING EDUCATION several times in recent years.

Three charts have been prepared to indicate the distribution of course work in this new five-year curriculum. Figure 1 presents the overall distribution of work in the entire curriculum; Fig. 2 shows the percentage distribution of work within the pure and applied physical science areas; and Fig. 3 shows the percentage distribution within the humanistic-social area. Each chart totals 100 per cent, and the distribution is based upon quarter credit hours of work.

As shown in Fig. 1, 22 per cent of the credits are in the pure physical science area including mathematics, chemistry, and physics, 57 per cent, in the applied physical science or engineering area, and 21 per cent, in the humanistic-social area. The work indicated as elective in the engineering area may, if the student desires, be taken in the pure physical sciences, but the electives indicated in the humanistic-social area are restricted to that field.

As shown in Fig. 2, 24.7 per cent of the work in the physical science areas is devoted to mathematics and mechanics. New required additions in this unit include a course in differential

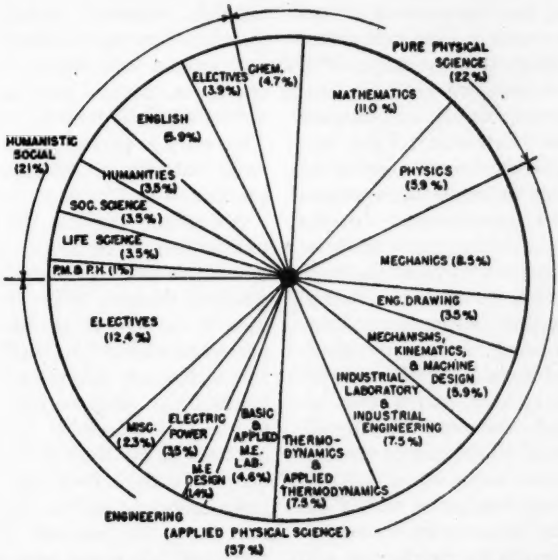


FIG. 1. Percentage distribution of credits in five-year mechanical engineering curriculum.

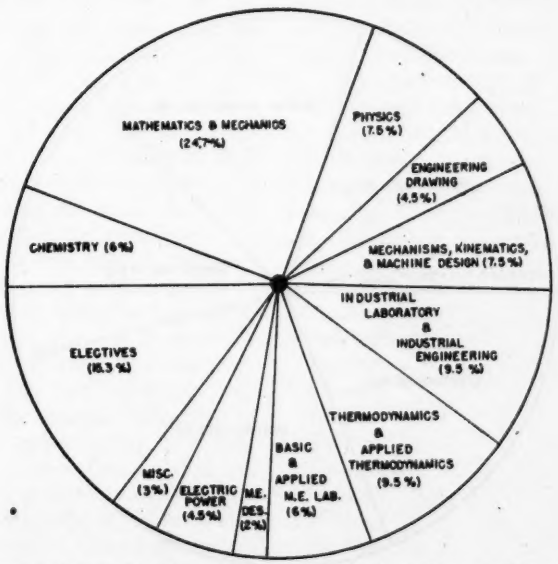

MATHEMATICS & MECHANICS (24.7%)
PHYSICS (7.5 %)
ENGINEERING DRAWING (4.5%)
MECHANISMS, KINEMATICS, & MACHINE DESIGN (7.5 %)
INDUSTRIAL LABORATORY & INDUSTRIAL ENGINEERING (9.5 %)
THERMODYNAMICS & APPLIED THERMODYNAMICS (9.5 %)
BASIC & APPLIED M.E. LAB. (6%)
ME. DES. (2%)
ELECTRIC POWER (4.5%)
MISC. (3%)
ELECTIVES (16.3 %)
CHEMISTRY (6%)

FIG. 2. Percentage distribution of engineering and physical science credits within five-year curriculum.

equations and the replacement of hydraulics by a course in fluid mechanics. The second highest percentage, 15.2 per cent, is work elective by the students. Thermodynamics and applied thermodynamics consume 9.5 per cent of the time, and work in the industrial laboratories and in industrial engineering, an equal percentage. In the thermodynamics field not only are basic courses in thermodynamcs required, but, in addition, courses in internal combustion engines, steam power, heating and ventilating, and in refrigeration. The industrial laboratory courses have been integrated into a new sequence of seven courses in "materials and processing." The first of these is a lecture course required of all students before registration in any of the other units in this sequence and includes basic work in metallurgy, and pattern design. The remaining courses in this sequence include work in foundry, forging, welding, heat treating, powder metallurgy, machine tool operation, machine shop practice, wood technology, die casting and plastics. This work is partially lecture and partially laboratory demonstration and practice.

Seven and one-half per cent of the time is devoted to physics and an equal amount to mechanisms, kinematics and machine design. Six per cent of the time is devoted to chemistry, and six per cent to basic and applied mechanical engineering laboratory. The basic mechanical engineering laboratory courses are scheduled in the last two quarters of the third year and the first quarter of the fourth year and include basic instrumentation and laboratory experience fundamental to the more advanced laboratory courses. In the applied laboratory courses the student

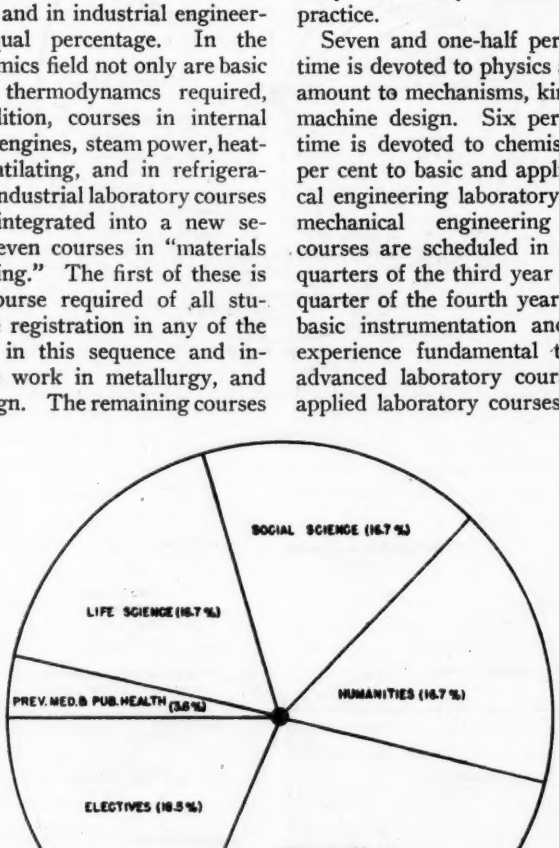


FIG. 3. Percentage distribution of credits in humanistic-social area of five-year mechanical engineering curriculum.

may choose three courses from the fields of industrial engineering, machine design, internal combustion engines, steam power, heating, ventilating and air conditioning, and refrigeration.

Four and one-half per cent of the time is devoted to electric power, four and one-half per cent to engineering drawing (not including application courses in mechanisms, kinematics, and machine design), three per cent to miscellaneous engineering subjects such as seminar, inspection trips, etc., and two per cent to senior mechanical engineering design. This last unit includes a choice of work in the fields of advanced machine design, internal combustion engines, steam power, industrial engineering, heating, ventilating and air conditioning, and refrigeration.

Figure 3 shows the distribution of the work in the new humanistic-social area added to the curriculum. By far the largest unit in this area is English with 27.8 per cent. The second largest is the elective area with 18.5 per cent. The remaining distribution is life science, 16.7 per cent, social science, 16.7 per cent, humanities, 16.7 per cent, and preventive medicine and public health, 3.6 per cent. Although the elective area is the next largest indicated, this is true only if the very minimum amount of work required in any of the other units is completed. The English unit requires a minimum of nine credits of freshman engineering English plus two additional advanced English courses appearing in the fifth year, and including both public speaking and correlation of English with engineering report writing. The preventive medicine and public health unit is a two quarter-credit course required of all students in the first year. Work in the life science area is to be taken in the second year and may be elected from prescribed sequences in any one of four fields: general biology, general botany, general zoology, or psychology. The social science unit is to be taken in the third year, and the student may elect either a social science sequence, a labor problems sequence, a political science sequence, or a sociology sequence. The humanities are scheduled for the fourth year, and the student may select sequences either from the humanities, philosophy, English, history, or fine arts and music. Although the student has a reasonably wide choice of units in which he may choose work, the recommended units are general biology in the life science area, social science in the social science area, and humanities in the humanities area. These specific units are recommended as the courses are designed to cut across the various fields of human endeavor and to result in the combination giving the broadest possible liberal education. If the minimum amount of work is selected in each field, a total of 44 quarter credits would be taken, whereas the minimum number of credits required in the entire area is 54. The remaining 10 or fewer credits of work may be chosen from any of the following fields:

Anthropology
Astronomy
Botany
Classics
English
Fine Arts
Geography
Geology
History
Humanities
Journalism
Languages

Marriage
Music
Philosophy
Political Science
Preventive Medicine and Public Health
Psychology
Social Science
Sociology
Speech
Zoology

It should be noted that mathematics, physics and chemistry are absent from this group, as electives shown in the physical science area may be chosen from these fields.

The changes here enumerated are the most wide-spread which have been made in the University of Minnesota Mechanical Engineering curriculum during this century. This is true not only because of the inclusion of the additional year's work in the social-humanistic area but also because of deletions of former required and elective courses and the reorganization and additions to the required work. Although it is felt that much has been accomplished toward the liberalizing of this mechanical engineering curriculum, undoubtedly additional changes will be made until a fixed pattern evolves which will best accomplish the aims.

Although this article deals primarily with the integration of a liberal educational background into a basic mechanical engineering education, it should be pointed out that the humanistic-social area discussed will be essentially the same throughout the University of Minnesota's Institute of Technology. The author wishes to acknowledge that the evolution of this liberal fifth year resulted from the leadership and inspiration of Dr. S. C. Lind, Dean of the Institute of Technology, and Dr. T. L. Joseph, Assistant Dean and Chairman of the Five Year Curriculum Committee. The reorganization of the basic mechanical engineering curriculum was accomplished through the leadership of Professor Frank B. Rowley, Head of the Mechanical Engineering Department, and Professor B. J. Robertson, Chairman of the Mechanical Engineering Curriculum Committee.

Some Observations on Learning*

By L. M. K. BOELTER

Chairman, Dept. of Engineering, University of California, Los Angeles

The purpose of this paper is to present some observations on the learning process resulting from experiences with students. These observations arise from classroom and laboratory student-instructor contacts and from interviews, and will be discussed in terms of the present formulation of the laws of learning as presented by Thorndike based on a definition of learning as the modification of native reactions. It is not maintained that these laws (1)† are mutually exclusive or that they form a complete set. Briefly, Thorndike states

"(1) *The Law of Effect:* The strength of a response to a given stimulus is increased or weakened according as satisfaction or annoyance results.

(2) *The Law of Frequency:* The strength of a response to a given stimulus is increased in repetition of the act and is decreased with non-performance.

(3) *The Law of Readiness:* When the student is ready to respond to a situation, to do so is satisfying; not to be allowed to respond is annoying, and vice versa if not ready."

Experimental results are presented to substantiate the assertions if the former are available and applicable. The paucity of experimental results requires no apology as the same situation exists with respect to almost any field of engineering. Bills (2) states "The most inclusive definition of learning identifies it with all modifications of behavior." The following categories, however, are excluded:

a. Changes in the physiological structure (sensory, muscular or skeletal) outside of the nervous system.

b. Changes in the nervous system directly resulting from maturation.

c. Changes resulting from fatigue, and temporary alterations of the thresholds of excitability.

Learning includes the entire group of relatively permanent modifications in behavior patterns which result from previous interaction with the environment. Learning may be divided into two types (which are not mutually exclusive) for the purposes of study:

a. Perceptual motor learning, that is, the formation of habits or acts of skill,

b. Ideation learning, this is, memory.

". . . habit formation involves the fixation of definite response patterns so that the actual movements are later reinstated, whereas memory involves the

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† Numbers in parentheses refer to Reference Table.

establishing of a symbolic substitute for the original process which is later revived and functions in the absence of the original" (2).

The memorization of algebraic symbols, as substitutes for the names of the physical variables, is in part a mental (and/or vocal) habit. Mechanical drawing is an act of skill but the learning time may be reduced by symbolically thinking of the components of the correct technique.

The explanation of the technique of solution of a problem cannot be stated with certainty. The solution is the discovery of a mode of adjustment, the adaptation of means to the particular end. The correct accomplishment results in a process of fixation. The perfected act is retained until reinstated later or generalized for use in new situations. The unaided learning process is usually regarded as a "trial and error" procedure, with insight or appreciation of the situation. The usual educational method involves learning with tuition. Four modes may be distinguished:

a. The artificial prevention of errors.
b. Aiding the learner to put through the corrected solution, by the incidental elimination of errors.
c. By verbal instruction (concrete and abstract).
d. By demonstration, with consequent imitation by the learner.

When the correct solution has been found and incorrect solutions eliminated the process becomes fixed. The mode of fixation is not clear but it is no doubt intimately concerned with the effect of the stimulus upon the learner. Tolman (3) feels that the foresight of a goal predicates all learning.

An Analogy

The learning process implies that the student (subject) is subjected to external stimuli. The educational process is designed to "order" these stimuli. The system may be likened to an electrical circuit (4). The sources of the stimulation are analogous to the transmitter. The subject is the receiver and the environmental factors contribute to the impedance of transmis-

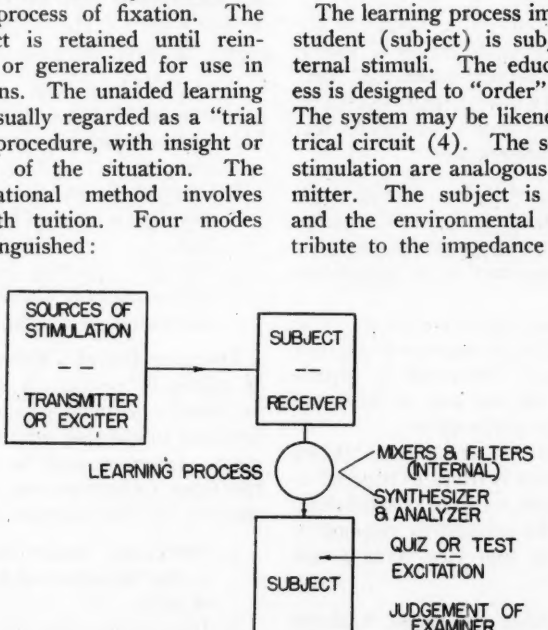

Fig. 1. The learning circuit.

sion. The resulting equation may be written in the following form:

$$\text{Response of subject} = \frac{\text{stimulus}}{\text{impedance of the complete circuit}} \quad (1)$$

It may be shown that these variables are a function of time. A generous extrapolation might lead to the conclusion that response at resonance may describe a genius.

The effectiveness of instruction may be determined by measurement. The instruments required to measure individual achievement should be independent of the examiner and of the environmental factors (at the time the measurements are obtained) so that, ideally, the impedance term now represents the internal impedance of the subject. To an outside observer the learning process appears to be coupled circuit in which the subject is both the receiver and the transmitter. Diagrammatically the circuit may be represented as shown in Fig. 1. Some of the variables which contribute to the magnitude of the numerator and denominator of equation (1) will now be presented, always in reference to the student in engineering in a normal undergraduate curriculum.

Stimuli

The stimuli may be classified as:

1. Environmental experience. The student may learn by the observation of the behavior of nature or of the engineering works which he encounters in his everyday routine. These observations should not be confined to those presented in the laboratory or in a lecture demonstration. He must also have actual contact with structures, processes, machines and circuits. Remunerative employment in various phases of the business structure will contribute tremendously to his development. The church, newspaper, theatre, radio and extracurricular activities provide important sources of stimulation.

2. Knowledge gained from relatives and friends. Too often a student feels that he cannot learn anything worthwhile from his parents (although in the case of the average student most of his earlier experiences and the corresponding response pattern is due to their influence). He forgets that his father knows a great deal about the laws of mechanics (if a pre-machine age farmer, proper loading of vehicles or harnessing of horses are examples) although he has never formulated them, or that his mother has available many data on heat transfer and chemistry as a concomitant of her cooking experiences. Further, social contacts form an important link in the learning chain. Many students feel that they must study independently. A proper balance between individual effort and group effort seems to be a desirable goal.

3. Stimuli due to the instructor in his capacity as lecturer and teacher. Students often depend entirely upon the lecturer for stimuli rather than to also employ the other sources herein mentioned. The instructor is the source of stimulation in directions other than the subject material at hand. Students subconsciously reflect his linguistic and physical mannerisms. Also, for instance, if the instructor lacks and omits consideration of satisfactory and economical computation habits, the student will likely not fill this gap in his educational experiences.

4. Stimuli due to reading. The library of the average student is woe-

fully inadequate. The inadequacy is usually explained on monetary grounds but this point of view cannot be defended. Further, the student does not appreciate the importance of having available supplementary references, current literature, and the works of the Masters. Hutchins in "The Higher Learning in America" states that students must obtain basic training through the works of the Masters. Lucretius, Aristotle, da Vinci, Galileo, Newton, Leibnitz, Descartes, Planck, Helmholtz, Fourier, Rankine and Clausius may be mentioned, among others, as worthy of attention by engineering students in this connection. Quoting Hutchins (5).

"Ordinarily what he (the student) knows about them he learns from texts which must be at best second-hand versions of their (the authors of the classics) thoughts." ". . . textbooks have probably done as much to degrade the American intelligence as any single force."

Impedance, primary abilities

The variables of the denominator will be discussed in the following paragraphs. The terms "capacitance" (capacity), "inductance" (inertia) and "resistance" are in common use as applied to individuals.

Thurstone has presented data indicating that at least seven independent primary abilities constitute the operation of the intellect. (6). Other primary abilities may be segregated, as a result of future research, but a general discussion of the seven primary abilities will prove profitable. Fifty-six psychological tests were administered to 240 college students over a period of 15 hours. The tests were constructed to include a wide variety of verbal, visual and numerical material. The results of these tests were analyzed by the multiple factor technique which segregates the factors presented by the test. These factors are the abilities utilized by the subject in the solution of the task.

The seven (tentative) primary abilities will be enumerated and discussed:

1. *Number facility*

   The response of the subject is restricted to numerical thinking and includes, to a large degree, the numerical speed operations. This factor is less conspicuous in those numerical problems which involve reasoning or the formulation of a problem in quantitative terms.

2. *Word fluency*

   This factor is prominent in those operations in which the subject must supply words in a given context. The corresponding primary ability is limited to the recall of words and does not involve verbal reasoning.

3. *Visualization*

   This factor includes visualizing objects in one, two and three dimensions.

4. *Memorization*

   It may be concluded that a good memory may be an attitude without regard to the specification of the character of the task (words, names, numbers).

5. *Perceptual speed*

   This factor implies the ability to observe objects and choose the distinguishing characteristic. It also accounts for the individual who can scan a drawing or a page of names (or numbers) and find the desired item quickly.

6. *Induction*

The subject must discover a principle or rule which governs the behavior of the system (or the material presented in the task). For instance what rule governs a set of numbers: 1–2–4–7–11–16–22. If induction is a primary ability, then some people may be superior in deductive thinking, although not in inductive thinking. Further experimental evidence is needed before it can be said that originality and inventiveness are involved in the primary ability, induction.

7. *Verbal reasoning*

This primary ability, Thurstone suggests, might be called verbal relations or deduction. It implies the ability to construct verbal analogies, match quotations with those of similar meaning, and to make numerical estimates which require deductive reasoning.

The test results indicate that deduction, involving the statement of certain premises the subject to select one of several inferences as correct, may be another primary ability. Another, still somewhat obscure, primary ability seems to be characterized by some of the elements of precision.

The exact number or nature of the primary abilities is subject to further experimentation and interpretation. The extent to which primary abilities are native and acquired (as the result of training) is a basic educational problem.

The present task of the engineering instructor is to aid the student to discover his effectiveness in each of the primary abilities. The mere marking of problem sets and examinations is not sufficient. Pointing out specific errors is not adequate. The errors must be traced to the lack of effectiveness in a primary ability, in other words the errors must be classified.

As our knowledge of the primary abilities increases, it may be possible to base a selection system upon the performance of the engineering neophyte in each factor. After the psychologist has isolated the factors, engineers must decide to what extent each ability is required by the prospective student who wishes to enter a particular classification of engineering. We must not conclude that our present criteria are adequate guides, but must determine the factors which are included in the several criteria.

Thurstone suggests that a student who attains a low score in visualization ability will have difficulty in descriptive geometry. F. H. Cherry (7) has studied the records of several senior classes in Mechanical Engineering at the University of California and has found correlation between grades in descriptive geometry and the chances of graduation.

Impedance, Instructor

The next group of variables to be discussed will be concerned with certain methods which the instructor may employ to reduce the impedance of transmission and reception. Let us examine the laws of learning as formulated by Thorndike. Those laws suggest that the instructor attempt to provide a motive for the various tasks. Trow (8) states, "Improvement is more rapid when the learner comprehends his task and recognizes its harmony with his desires and needs." Many students have chosen to study engineering on very meagre evidence. They are unaware of the scope of en-

gineering and the standards of the profession. The student often finds himself in college because he vaguely hopes to better his social position as contrasted with that of his parents, or because of social pressure. He registers in engineering because he has been told that facility in mathematics is a prerequisite of an engineer or because he is interested in structures and the operations of machines. A freshman recently expressed the thought that the author was an engineer because he was muscular. He is attracted by the glamour which surrounds may of the newer fields of engineering. He has also been told that engineering training will prove effective no matter what his life work will be. Or he may have decided to pursue engineering because of an apparent weakness in other fields, such as the languages, history, literature. Adequate motivation assumes the aspect of orientation and should result in a gradual change from the immature point of view of a high school graduate to that of a professional engineer.

The student is a strict utilitarian. He expects to use his education to earn a livelihood. The instructor must inspire the student to desire knowledge for its own sake. The proper combination of the utilitarian and academic aspects of knowledge will lead to student self-stimulation. The ultimate aim of instruction is to cause the student to produce ideas and solutions of his own without pressure from the instructor. Referring to the analogy, the student must generate an intellectual counter electromotive force. Recitations, seminars and reports serve as indispensable outlets of the individual student accomplishments.

Recognition of the truth and the beautiful by the student will follow as a direct result of inspiration by the instructor. The aesthetic appreciation of nature and of man's works will be extended simultaneously with the facts of engineering. Instruction in the physical sciences may be humanized by the addition of a discussion of the historical significance and the sociological implications of engineering progress. In addition, the discussion of the personalities of the great contributors to scientific knowledge tends to create student interest.

The instructor-student relationships may partially assume the character of the employer-employee status. The importance of mutual understanding and joint accomplishment will be apparent. The student will gradually approach the lower elevations of instructor experience level. The instructor needs to visualize the experience level of individual students and accommodate his methods to the range displayed. Classroom educational experiences should be made as "real" as possible.

The student often feels that the instruction is theoretical and that he must wait until he finishes college before the actual, and real, experiences begin. The future employer (often a graduate) has expressed similar views. The student must be caused to realize that he is idealizing actual systems (9).

Modern engineering instructional methods involve a schedule in which the most complete idealizations and the corresponding properties of materials are presented early in the curricula. The gap between the first idealization and the corresponding actual systems is gradually narrowed as the educational process proceeds. Predetermination of the behavior of actual systems requires the synthesis of ideal

systems. This concept will serve as a powerful motivating agent.

The instructor may still further reduce the transmission impedance by using a universal engineering language. Each new development in any field of knowledge results in a barrage of new terms and nomenclatures. The instructor should not subdivide engineering into compartments, each destined for a separate pigeonhole in the brain of the student. A "breakdown" is essential in certain stages of the instructional process but it must be accompanied by corresponding synthesis.

The grading system may be arranged so that it will serve as a motivating agent provided suggestion and correction methods are employed. The attention of the student must be directed to the classes of errors which are made as well as the errors themselves (12).

Learning should not become a mental marathon. Fatigue and listlessness will result. Fatigue causes an increase in the number of errors and reduces the output (13). Flexible assignment schedules allow the student to balance his load. The student should not be required to take too many courses at one time. According to the law of frequency varying amounts of practice or drill tend to produce a corresponding improvement in performance. Further practice interspersed with periods of no practice tends to eliminate fatigue and shorten the total learning time, though longer intervals may lower the performance level (14). Unless the student can control his study time he will not be able properly to arrange the practice periods but must resort to concentrated short-period over-learning (15) (16) in order to meet the course requirements. The instructor may strategically space reviews in order to increase student retentivity. The slope of the forgetting curves (per cent remembered against time) is very steep for the first day. Test data indicate the desirability of immediate reviews. The frequency of the reviews may be reduced as time progresses. Quoting from Pressey (17) "only material of undoubted value should receive such treatment, for undoubtedly many items now included in practically any course might as well be forgotten."

Practical suggestions to teachers by Pressey are listed in Appendix III.

Impedance, transfer of training

Transfer of training is a phase of the broader problem involving the utilization of what has been learned. "To what extent and in what way will the acquirement of skill, understanding and attitude in one subject or topic or in one type of situation influence skill, knowledge, understanding, and attitude in another subject or topic or in a very different situation?" (18). Many data are available on languages but few on the sciences. Transfer takes place when the tasks involve similar procedures but if the tasks involve different procedures from the original, very little if any transfer takes place.

"Drill in arithmetic computation appears not to transfer to problem-solving in arithmetic." Pressey (19) states transfer takes place in proportion as the material is similar, and it is increased if there is teaching for transfer. A widely used text in Mechanical Drawing including many apparently unrelated subjects could be rearranged for simple transfer teaching because two constructions and twelve definitions (concepts) were found by one of Pressey's students to constitute the total essential geometrical background involved. Considered development of

methods of definition in a science course can be transferred to non-science definitions.

Thorndike trained six subjects to estimate the area of different shapes, before and after training in the judgment of area of rectangles, keeping them informed of their errors. Slight improvement resulted. Training in the judgment of line lengths from ½ in. to 1½ in. long did not yield transfer to estimating line lengths between 6 and 12 inches.

Where actual rules of procedure of general applicability can be set up, transfer is positive. Judd trained 50 boys to shoot at underwater targets. After reaching a given degree of perfection he described the physical theory of refraction to one half of the subjects. The other group were told nothing. When returned to target shooting both groups behaved similarly at first, but later the boys who possessed the general principle forged ahead. Transfer from addition to subtraction was found to be zero; addition to multiplication, negative; addition to division, zero.

The matter of transfer of training seems to be one of the most important in the educational process. The instructor normally assumes transfer takes place. It is only when he reads quiz papers that he realizes the lack of transfer. The following example aids in the understanding of the transfer phenomenon:

Stimulus (S_1) calls for the response (R_1) as the result of training. Then to substitute stimulus (S_2) and expect the same response (R_1) means that the connection which has been made as the result of learning must be weakened and/or broken. In other words, $S_1 \rightarrow R_1$ partially inhibits $S_2 \rightarrow R_1$. However, having established $S_2 \rightarrow R_2$ does not interfere with establishing a new connection $S_2 \rightarrow R_1$. In the latter case positive transfer will occur, while negative transfer will occur in the former.

Transfer may be discussed in an enlarged arena. The statement is often made that an engineering training is superior no matter what field of activity the graduate may enter. It has been written elsewhere, that no data exist which will reveal whether a successful business man would have been a better or a worse business man had he not had an engineering education. It would appear that if the methods and generalizations used in engineering are applicable in other fields, that a transfer might result. However, the engineer usually is trained to deal with repetitive systems and has available many tools with which to handle these problems. His training in solving problems involving the use of statistical methods is weak. This defect should be remedied if greater transfer is desired to other professional fields.

Transfer does take place for similar procedures. This statement should be one of the foundation stones of the organization of courses and of curricula. An inference is that the manner of presentation and the smaller generalizations are more important than the material, which serves as a vehicle. The technics and procedures, which are satisfactory and correct and are used in the industry and in the social structure, should be used in the educational system. The forces of transition from college to the industry will thus be reduced. The college graduate will receive more respect directly after commencement.

The application of the transfer mechanism to learning in the sciences has not been subject to extensive research. Here lies a fruitful field for

engineers who have or intend to enter the teaching profession.

Applicational transfer is the basic problem of engineering instructors. General methods of procedure can be taught but learning a rule does not insure correct usage or application. Pressey (20) reports that an electrical repairman in five minutes solved the defect in the wiring of a house occupied by a group of electrical engineering students.

Impedance, Ends of Engineering Training

A clear concept of the aim of the engineering training should exist in the mind of the student. During his college residence the engineering student experiences an ever-expanding view of the functions of an engineer; in fact, many experience a complete inversion. They come to college, expecting to become operators, designers, experimenters, that is, specialists in a particular subdivision of a field of engineering. Then as contact with the industry and the social structure increase, students observe that many excellent opportunities exist for the man with a general training. The following specifications for basic training in engineering may serve to aid the growth process:

1. Expression
   Oral and written English, Grammar, Rhetoric, Logic, Engineering Reports: Pictorial; Drawing, Descriptive Geometry, Drafting, Design: Symbolic; Mathematics (see Lewis and Randall, "Thermodynamics," page 26, for the statement by Willard Gibbs, "Mathematics as a language").
2. Energy Fields
   Mechanical: statics, kinetics, dynamics (undirectional and periodic) of fluids and solids including acoustics and hydraulics.
   Electrical: electric, electrostatic and magnetic circuits, electronics.
   Thermal: thermodynamics, heat transfer, light.
3. Experimental Behavior of Ideal Systems (usually called fundamental laws), as presented in Chemistry, Geology, Life Sciences and Physics.
4. Properties of Materials.
5. Mensuration.
6. Experimental and predicted behavior of Actual Systems.
   Application of items 1–5 above to actual processes, machines, structures, circuits and animate * objects. This procedure implies the superposition of energy fields and also involves phases such as design, construction, manufacturing, sales, and operation. Fields of knowledge which must here be considered integrally with engineering are Economics, Psychology, History, Social Sciences, etc.

It will be observed that the subdivisions 1–6 are not stated in the sequence which is in pedagogical vogue today. Instruction now proceeds simultaneously on all fronts. Portions of each subdivision appear in the organized courses of the engineering curricula, namely, Physics, Chemistry, Mathematics, Heat Power Engineering, An-

* For example, the forces exerted on and by a driller operating on air gun or the flow of blood through the arteries.

alytical Mechanics, Strength of Materials, etc.

Referring particularly to the class "expression," an appreciation of the complementary aspect of these modes, which are available to the engineer, will aid the student in his classroom work as well as to indicate the reasons for requiring him to take the corresponding courses. The vocabulary of the engineering student is likely to be limited to words necessary to describe inanimate objects unless the humanities play an important part in his "learning plan."

Impedance, student

The impedance offered by the student may be characterized as "internal." The engineering student should become conscious of the learning process as an essential to the application of rational and tested laws of learning. According to Pressey (21) "the essence of learning is that a correct or better response to a situation should be found and should be established. The correct answer is the one which is recognized as fitting in with all phenomena involved and thus solving the immediate problem. From a more general point of view, the correct answer is the answer which fits in with and brings to fruition the interests and incentives involved. Review should establish the adequacy of the correct solution."

An examination of the lecture notes of a student often reveals a deficiency of material on the initial phases of a problem. Introductory remarks, definitions and the description of the actual system to be idealized are not adequately represented in the notes. Much space and effort is devoted to the mechanical manipulation of equations. Again too little of the interpretation, applications, and conclusions appear. The student should be encouraged to take notes only if this procedure does not interfere with a thorough comprehension of the data presented by the instructor. A statement of the exact references to the material of the lecture is very important. Another important contribution to a high internal impedance is the status of the art of listening. This variable is extremely important when instruction involves the lecture and recitation systems.

Few students listen carefully and retain accurately even for short periods of time. Neither can we maintain that the student understands what he reads (5). Still less in number can listen and take notes simultaneously. As a corrective measure, a student should listen to a reading by a friend for periods of increasing length until the length of a lecture period is reached. The listener is to repeat accurately the essence of each reading. After accomplishment of this end, simple algebra problems should be solved simultaneously with the listening assignment, also represented in periods of increasing length. Training of this character will improve the student's receptivity, that is improve his capacity to listen to a lecture and to take effective notes simultaneously. Notes taken under this scheme represent the equivalent of the original presentation plus one review.

The student must study his own physiological and psychological reactions. It is important to be familiar with the underlying principles of the behavior of a pump, engine, or radio set, but it is even more important for him to know himself. Test data upon his performance must be obtained and remedial measures applied, if neces-

sary. The student generally learns about himself by the "hit and miss" method, not by the application of the scientific method (which he is using on inanimate systems in his classroom work).

Some factors, in addition to those mentioned in the foregoing discussion, which deserve special attention are the following:

1. Physical endurance and the condition of the sense organs, particularly those of hearing and sight. Also the amount and kind of exercise needed. Adequate provision for fresh air and sunlight.
2. Study environment, referring to light, noise, interruptions, and study companions.
3. Budget of total time.
4. The determination of the number of tasks which the student may handle simultaneously throughout the semester.
5. Fraction of the total development which is to be formal engineering training.
6. Required balance between actual and vicarious experiences.
7. Schedule of alternate study and relaxation periods. Concentration (active attitude in learning) is not possible until complete relaxation (between learning periods) has been accomplished.*
8. Proper spacing of reviews and other study habits.
9. Acquisition of a sense of relative importance of experiences gained.
10. The development of a rational and individual method of attack on problems (9). Following is a proposed method which may have merit as applied to problems which yield to algebraic manipulation:

a. Examination of the behavior of the actual system (must be based on experiment or extrapolation of experience on similar systems). This procedure is equivalent to statement of the problem.
b. Recognition of the energy fields involved; segregation of the variables.
c. Mental (or experimental) construction of an ideal system (omitting the unimportant variables).
d. Application of the laws of behavior of the ideal system to obtain a solution of the ideal system.
e. Comparison of the behavior of the actual system with that of the ideal system. If the behavior of the former has not been adequately predicted a more complicated ideal system must be constructed and the process repeated.
f. Explanation of the deviation of the predicted results (behavior of the ideal system) from the behavior of the actual system, referring to the omitted variables noted under (*c*) and the laws to which the ideal system was subjected.
g. Formulation of a report.

Subdivisions *a-c* constitute the usual processes of analysis, while *d* and *e* offer opportunities for experience in synthesis.

Problems may also be solved by examination of the behavior of

* This statement is not to be confused with the experimental data indicating that greater rates of, and more effective, learning are possible under the "active" attitude. See Wills, "General Experimental Psychology," pages 254–55, 330, 370, and 408.

the prototype and of models (and the application of model laws), or by solution of an analogue. In every case observation of the behavior of the actual system is necessary. For example, it is questionable whether a student will gain benefit from the design of an object, unless he has at least seen a similar object.

11. Extension of training to the solution of and the discussion of everyday problems, that is, the student should make his own applications.
12. Formulation and compilation of those phenomena encountered which are not understood completely. A review of these items at proper intervals will allow the subconscious mind to prepare solutions.
13. Preparation of a list of those items needed at long (in terms of the forgetting curve) and irregular intervals in order to reduce the load on the memory.
14. Preparation of a running list of unfinished tasks.
15. Correlation of various experiences. Application of knowledge gained in one field to other fields, transfer of training.
16. Adaptability to new (transient and periodic) environments both in and out of the classroom.
17. Adaptability of the reaction pattern to the aptitudes and skills required of an engineer.

Instruments

The techniques which are necessary to measure the efficacy of the various learning methods should be considered. The examination, as an instrument, has been discussed by the author in the paper entitled "The Comprehensive Examination; Does it Apply to the Engineering Curriculum?" (11). In general, control sections must be contrasted with experimental sections in order that a comparison of the progress may be made. Pressey (12) and Trow (14) present clearly methods which are applicable to the classroom.

The capacity term, that is, the native intelligence, has not been discussed. Its magnitude will obviously fix the maximum response for a particular individual. The student may often subject himself to tests which will reveal his progress, independent of the classroom evaluation. Care must be taken to obtain objective data and avoid erroneous conclusions. In all cases the instruments (and interpretation of readings) must present the appropriate impedance.

Learning Curve

The rote learning curve, Fig. 2, has been rationalized by Thurstone (22). The differential equation may be written as:

$$\frac{dp}{dT} = \frac{2k}{\sqrt{m}} p^{3/2}(1 - p)^{3/2}, \qquad (2)$$

which implies that the rate of reduction of errors is a constant (k) times the probability that the initiated act will end incorrectly and that the rate of increase of successes is the same con-

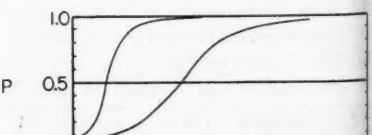

Fig. 2. The learning curves, see equations (2) and (3).

stant times the probability that the initiated act will end successfully.

p = proportion of acts initiated which lead to a successful conclusion,
T = time.

The solution of the differential equation is:

$$\frac{2p-1}{\sqrt{p-p^2}} = \frac{kT}{\sqrt{m}} + z_0;$$

$$z_0 = \frac{2p_0 - 1}{\sqrt{p_0 - p_0^2}}, \qquad (3)$$

where (k) is the learning constant, which is the number of errors eliminated per unit time, a constant of the individual; $m = se$ where s = effective successes and e = total errors, "m" depends upon the character of the task. p_0 implies native ability at the beginning of the task. The form of the learning curves have been substantiated by experiment.

The interpretation of this rote learning curve in terms of engineering instruction may include the following items:

Much of the information presented in the classroom in the earlier portion of a particular course or of a subdivision of a course, or of a particular problem, description, definition, symbols, evaluations is rote to the student. The degree of rote learning depends on the articulation of one course with another and other factors. As the work in a course progresses, (k) increases, and (m) decreases (less rote material will be needed, the instructor has laid the background) and the point of inflection (p) moves toward the origin (always located at $p = 0.5$). The learning curve then becomes almost logarithmic in character. The student grasps the introductory essentials (which is rote material unless he has had previous experience) very quickly which is another way of saying that (k) has been increased.

Even though the inference is not quite correct it is presumed that the learning curve of a particular student shifts from curve (1) to (2) in Fig. 3 as the student progresses in a course. Each student will have a certain learning curve at the end of a period of instruction which implies different constants in the equation of learning and the instructor must decide to what extent he wishes to gauge the speed of instruction by the response of the weaker student.

A heterogeneous task may be considered as the sum (using the principle of superposition which may not quite be applicable) of (r) homogeneous tasks. For instance let one task be difficult (curve 1) and another

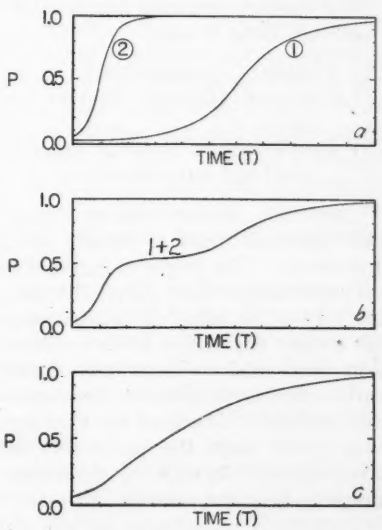

FIG. 3. Superposition of learning curves. (*a*) Curve 1, difficult task; Curve 2, less difficult task. (*b*) Summation of curves 1 and 2. (*c*) Summation of a number of learning curves.

be less difficult (curve 2), the sum will possess a plateau. The initial portion will be steeper (because (m) will be less) than the portion beyond the plateau.

Any number of curves may be added and may result in a learning curve which has a point of inflection practically coincident with the axis, as revealed in curve on Fig. 3c.

A conclusion may be drawn to the effect that periodic tests will yield results depending upon (k) the student's learning constant, (m) the character of the task, which he has been learning as well as depending upon the character of the test.

These conclusions are based upon rote learning analyses, but much material which is meaningful to the instructor may be rote to the student (initiate).

The memory function has been divided into three phases:

(1) Fixation (or acquisition).
(2) Retention (between fixation and use).
(3) Reinstatement (revival inducing recall and recognition).

Emotional embarrassment, shock and distraction have a definite effect upon recall. The proper response does not result under these external stimuli but may occur later. This paragraph has distinct application in the examination (oral and written) and during early interviews between instructors and students. Much of an examination (more than the instructor will often admit), depends on the proper functioning of the memory.

Effectiveness of Learning (2)

The optimum ratio of length of practice period to length of interval between trials has not yet been satisfactorily determined. Meaningful material gives different results than nonsense material. Delayed recall is more effective after distributed practice as contrasted with concentrated practice. These data seem to indicate that it is not desirable to delay study until just before an examination if the knowledge is desired at a later time.

Another experiment in which the length of the practice period was changed during the learning period indicated that the study effort should be massed during the initial stages of the learning period.

The interval between practice periods should be great enough to "drop out" conflicting habits but not great enough so that the rate of foregetting offsets the gain. Learning by parts progressively (1 and 2, 3, 1 and 2 and 3, etc.) has the advantage of shortening a complex task to a size commensurate with the ability of the subject but has the disadvantage of setting up position habits, which must be "broken up" when the parts are united.

This method is approximately that used in presenting work in engineering courses. The position habits generated by the semi-arbitrary (yet historical) presentation of a curriculum by courses were often not eliminated for and by the student as noted earlier in its paper.

Further research has indicated that the majority of students prefer the part-progressive method, but that a sizable minority prefer the whole method. Whole learning achieves integration, which in part-learning must be attained by extra effort. Individuals vary in their span and scope of attention as well as having been trained in one method (usually the part method) thus accounting for the preference.

The learning time increases with the size of the assignment. Thurstone has derived an equation, which has been experimentally substantiated for rote learning:

$$T = \frac{c}{k} n\sqrt{n - a} = \frac{c}{k} n^{3/2}, \quad (4)$$

where T = total learning time,
k = learning constant of subject, average number of errors eliminated per unit time,
n = number of items in the list,
c = degree of perfection required,
a = memory span (amount which can be remembered at a single trial).

This law is probably applicable when the student is introduced to a new terminology and a new symbolism. It would indicate that the introductory acquaintance with a second problem involving twice the number of variables as the first will require 2.8 times the fraction of the lecture period devoted to the definition and description compared with the first problem.

The rates of learning of meaningful material as contrasted with rote material differ. Psychologists have concluded that the method of learning is probably different, resulting in a distinction between rote memory and logical memory. Rates of learning 4 to 9 times rote learning rates have been reported for prose and poetry respectively. These data have great significance to engineering teachers. If properties of materials are presented as isolated entities, the student responds as he would to rote instruction. If, however, the student is introduced, for example to the Wiedemann-Franz ratio of electrical to thermal conductivity, or to the kinetic theory relation:

$$k = \epsilon c_v \mu, \quad (5)$$

where k = thermal conductivity,
c_v = unit heat capacity at constant volume,
μ = coefficient of viscosity,
ϵ = numeric,

each relation being explained in terms of a hypothetical mechanism of the substance, the learning process revolves around more meaningful material.

The research data indicate that learning tasks which were pleasant require less time for completion than unpleasant and neutral tasks. Whether, or not, the material in an engineering course presents a pleasant aspect depends on many factors. It is well known, however, that some students are enrolled in some courses, the content and the manner of presentation of material and tasks of which is anathema to them. The inhibitive attitude of the student no doubt often results from earlier training, is based on prejudice or gossip, or is the result of a barrier caused by one unpleasant experience. The instructor also can do much to change a neutral material to pleasant material.

Material may be presented visually or auditorily or both. Contradictory evidence is available with respect to the effectiveness of the two modes of presentation. Much depends upon the type of imagery which the student has acquired.

Again evidence is contradictory regarding the advantage of oral articulation during learning. However, if grasping the meaning of a passage quickly by self-reading is the end, then articulation is a deterrent. If suppressing articulation is distracting then

the suppression is obviously a deterrent.

Many arguments are presented by students, and the faculty of some engineering schools, in favor of the recitation method. Data indicate that the memorization of all material, but especially rote, is accelerated by recitations and the effectiveness of learning depends upon the time devoted to recitation. Recitations have a greater learning value than self-reading but are increased in effectiveness by alternating with periodic silent reading.

Learning which takes place from a list is most effective for the first and last entries in the series. The reasons seem to be both position preference and reduction of interference.

Experiments have been conducted on simultaneous vs. successive presentation. The general conclusion is that the duration of exposure rather than the timing was the important variable. A good lecturer, therefore, presents drawings (not too complicated) and a complete outline of his lectures simultaneously with the lecture details.

Of the four types of tuition mentioned earlier, verbal instruction of the concrete type seems the best. Here probably lies the reason for the effectiveness of the recitation-problem method used in the little red school house. Instructions can be made too general.

Excitement, pleasure and feelings of well-being aid the learning process while depression and worry inhibit learning. Praise and blame, encouragement and discouragement, influence learning greatly. Boys improved more on reproof than girls, who gained most under praise. The inferior members of the group responded better to praise than the superior. In general, praise was superior to reproof. Each individual of college age will react differently depending upon his earlier experiences. The attitudes of success and failure, resulting from a comparison by the student of his own progress and that of others, have a large influence on learning. Rivalry and competition is a learning incentive of considerable strength.

The effect of environment such as the humidity, air velocity, odors, illumination, brightness of other sources, noise, prior activities, distraction due to activities of other persons, family and financial worries or joys, and extraneous printed matter, will be omitted from this discussion.

Some Physiological Variables (2)

Continuous learning for a four-hour period on one memorizing task has been shown to result in a small though appreciable reduction in effectiveness due to fatigue. Loss of sleep has also been shown to be detrimental to learning and attention; for the average individual an optimum learning rate for a long period of time exists as a function of the number of hours of sleep. Spurts in this rate may be accomplished by a reduction of the number of sleeping hours but if this process is continued a reduced over all output will result. This statement requires proof. Tobacco and alcohol affect learning adversely. The memory span is decreased during smoking and some time thereafter for non-smokers. Habitual smokers only experienced an effect one-half as great. Reductions of learning rates involving immediate memory to 30 per cent of normal after alcoholic stimulation have been recorded. Students should be made conscious of the reduced effectiveness due to these two causes.

Diet and gland behavior require much further attention before generalizations can be made. A drop in effectiveness, or increased variability, of mental processes accompanied fasting. Some students do not have sufficient (at least not proper) food. Often these men are found near the bottom of the class.

Thorndike concludes that in general no one under 45 should restrain himself from trying to learn in the belief that he is too old to learn. Many ill-adjusted students are afraid to leave the University for a period, during which time they have provided the gaps in their experiences and/or reached an appropriate level of maturation, because they believe or have been told that they will not be able to learn when older. Adults for instance have a much greater memory response for meaningful material than younger people. They possess a much richer background in logical associations and are therefore not forced to learn as much material by rote. This argument can be used effectively in the advice of poor students who possess latent capacity. A success in college in later life is better than a failure in early life.

Intelligence may be thought of as dependent upon the ability to learn and to solve problems. It can be shown that some types of practice are not related to general intelligence. At intervals an instructor must carefully study the content and techniques used in his courses in order to discover whether the grade given is a criterion of general intelligence, of a collection of skills, or of memorization. Various methods of reducing the impedance to learning have been proposed. Each one rests, at bottom, upon the fundamental laws of learning. The engineering instructor is invited to call these variables and laws to the attention of the student in the same spirit and with the same precision which characterize his presentation of data on inanimate physical systems. The student will respond quickly and effectively. The author has been guilty of unwarranted extrapolation, his only justification being the hope that some of the ideas will be shown to be correct or to be incorrect by experiment. The subjects of retention, forgetting, recall and recognition, imagery and abstract thinking are all directly applicable to engineering teaching but space forbids discussing them here. For variety and spice a quotation from Francis Bacon has been added as Appendix II.

Increased effectiveness of learning by the student is not urged in order that the faculty may still further load the student. The student often will not know how to use the time released. He has not yet accommodated himself to life in the metropolitan areas (referring to schools located in these districts) even though his family may have lived in cities for several generations. The student can be aided to use his leisure time effectively.

Individual instruction is still the corner stone of transmission of the art of engineering. Some of the training and material can, no doubt, after careful study be placed in lecture courses; but these must be amplified by recitation and laboratory activities. In particular a "library" of apparatus, all in automatic working order such as now found in museums, must be available to the student. This type of library, amplifying an adequate available library of reference books and literature will greatly reduce the amount of rote teaching necessary.

Appendix I

Laws of Learning—by Thorndike

From Sandiford, "Educational Psychology," pp. 196–202.

1. *The Law of Effect.*—This law is sometimes called the "law of satisfaction and annoyance." In Thorndike's * words the law runs: "When a modifiable connection between a situation and a response is made and is accompanied or followed by a satisfying state of affairs, that connection's strength is increased; when made and accompanied or followed by an annoying state of affairs, its strength is decreased." In other words, a *modifiable bond is strengthened or weakened according as satisfaction or annoyance attends its exercise.*

By modifiable bonds we means those that can be changed by learning. Some bonds we have seen, like those concerned with physiological actions (breathing and digestion), and some reflexes (the pupillary reflex, snoring, and shivering) are practically beyond our control. They belong to the non-variable forms of behavior. Others (sneezing, yawning, vomiting) are modified with extreme difficulty. Others again are modified with comparative ease. It is with this last group that the law of effect is concerned.

By a satisfying state of affairs Thorndike means "one which the animal does nothing to avoid, often doing things which maintain or renew it. By an annoying state of affairs is meant one which the animal does nothing to preserve, often doing things which put an end to it."

2. *The Law of Exercise or Frequency.*—This law has two parts—*Use and Disuse.* The *law of use* is—when a modifiable connection is made between a situation and a response, that connection's strength is, other things being equal, increased. The *law of disuse* is—when a modifiable connection is *not* made between a situation and a response over a length of time, that connection's strength is decreased. The phrase "other things being equal" refers mostly to the satisfyingness or annoyingness of the situation. "Practice makes perfect," but not if the resultant is painful. Nobody ever became perfect in sitting on a bent pin or in poking the fire with the finger.

Closely associated with the law of exercise are the factors of *intensity* and *recency.* A bright light, a loud sound, or concentrated effort leads to fairly permanent bonds with but few repetitions. Thunder and lightning make profound impressions on children; interest in a task makes it easier. Recency is the law of disuse turned the other way round, as it were. The bond recently formed can be recalled more easily than the one formed a long time ago. Disuse has not had time to play its part.

3. *The Law of Readiness.*—The law of readiness is: "When any conduction unit is in readiness to conduct, for it to do so is satisfying. When any conduction unit is not in readiness to conduct, for it to conduct is annoying. When any conduction unit is in readiness to conduct, for it not to do so is annoying." More briefly the law may be stated: *When a bond is ready to act, to act gives satisfaction and not to act gives annoyance. When a bond which is not ready to act is made to act, annoyance is caused.* The boy who is bursting to show his knowledge

* Thorndike, E. L., "Educational Psychology," vol. ii, Introduction.

is pleased if allowed to do so, and annoyed if the teacher ignores him.

Minor Laws of Learning.—In addition to the three major laws enumerated above, Thorndike gives *five* secondary laws. These are:

(*a*) *Multiple Response to the Same External Situation.*—Some external stimulus seems always to be necessary, but once a train of reactions is started, it provides its own stimulus for continuance. One thing leads to another. At bottom, these multiple reactions to a single situation lie at the basis of all learning. Through the laws of effect and exercise, the desirable ones may be selected and practiced. The higher the animal in the evolutionary scale, the greater the number and variety of its responses, and the greater its educability. Further, the higher the stage of learning the less the stimulus necessary to set off significant responses. A perched block may tell a geologist the glacial history of a country. From a few bones a paleontologist can reconstruct the extinct dinosaur. A slight stimulus in each case has led to a very complex series of responses.

(*b*) *Attitude, Set, or Disposition* determines the particular response that is made, and also whether it will be satisfying or annoying.

(*c*) *Law of Partial Activity.*—"A part, or element or aspect of a situation may be prepotent in causing response, and may have responses bound more or less exclusively to it regardless of some or all of its accompaniments." A pupil who has solved a number of puzzles or done a great number of intelligence tests "gets on to the thing" more quickly than one who has not had similar experiences. Similarly, to a trained mechanic a machine is not a blur or whirring wheels; he sees the connection of part to part and their relationship to the whole far more easily than one who is not so trained. Schooling in this sense is helping the pupil to notice and to react to the significant elements in a situation.

(*d*) *Law of Assimilation or Analogy.*—Situations having no original or acquired responses give rise to responses made previously to similar situations. The small girl of two years who triumphantly scooped up the water in a finger-bowl with a spoon was responding by analogy. The polite use of finger-bowls was unknown to her, but bowls with porridge in them were, so she responded to the water in a bowl as she had previously responded to porridge. In school, the most usual responses by analogy are found in the so-called "howlers." The boy who wrote "craven image" as part of the second commandment was responding by analogy.

(*e*) *Law of Associative Shifting.*—This is the conditioned response. A response may be shifted from one situation to another which is presented at the same time. There are numberless examples to be found in schooling. In learning to read, the situation is gradually transferred from element to element until the "ghostly, outline" of words is sufficient to arouse the reading response. Conditioning is so universal that it may truly be said that the teacher can get any response of which a pupil is capable associated with any situation to which he is sensitive.

Appendix II

Of Studies.

From the Essays of Francis Bacon —The Harvard Classics.

"Studies serve for delight, for ornament, and for ability. Their chief use for delight is in privateness and retir-

ing; for ornament, is in discourse; and for ability is in the judgment and disposition of business. For expert men can execute, and perhaps judge of particulars, one by one; but the general counsels, and the plots and marshalling of affairs, come best from those that are learned. To spend too much time in studies is sloth; to use them too much for ornament is affectation; to make judgment wholly by their rules is the humor of a scholar. They perfect nature, and are perfected by experience: for natural abilities are like natural plants, that need proyning,* by study; and studies themselves do give forth directions too much at large, except they be bounded in by experience. Crafty men contemn studies, simple men admire them, and wise men use them; for they teach not their own use; but that is a wisdom without them, and above them, won by observation. Read not to contradict and confute nor to believe and take for granted; nor to find talk and discourse; but to weigh and consider. Some books are to be tasted, others to be swallowed, and some few to be chewed and digested; that is some books are to be read only in parts; others to be read, but not curiously; and some few to be read wholly, and with diligence and attention. Some books also may be read by deputy, and extracts made of them by others; but that would be only in the less important arguments and the meaner sort of books, else distilled books are like common distilled waters, flashy† things. Reading maketh a full man; conference a ready man; and writing an exact man. And therefore, if a man write little, he had need have a great memory; if he confer little, he had need have a present wit; and if he read little, he had need have much cunning, to seem to know that he doth not. Histories make men wise; poets witty; the mathematics subtile; natural philosophy deep; moral grave; logic and rhetoric able to contend. *Abeunt studia in mores* (Studies pass into and influence manners). Nay, there is no stand or impediment in the wit but may be wrought out by fit studies; like as diseases of the body may have appropriate exercises. Bowling is good for the stone and reins;‡ shooting for the lungs and breast; gentle walking for the stomach; riding for the head; and the like. So if a man's wit be wandering, let him study the mathematics; for in demonstrations, if his wit be called away never so little, he must begin again. If his wit be not apt to distinguish or find differences, let him study the Schoolmen; for they are *cymini sectores* (splitters of hairs). If he be not apt to beat over matters, and to call up one thing to prove and illustrate another, let him study the lawyers' cases. So every defect of the mind may have a special receipt."

(3) (4) (5) (6)

* Pruning, cultivating.

† Insipid.

‡ Kidneys.

Appendix III

From Pressey, "Psychology and the New Education," pp. 419–20.

"Practical Suggestions for Teaching

The following suggestions are offered for helping pupils to remember their school work better.

(1) Always try to present what is to be learned in such a way that it is sensible and as meaningful as possible to the learner.

(2) Try to discriminate between essential and less essential things in the subject you are teaching. Once you have isolated certain

essentials, try to have them considerably overlearned. Remember that underlearning is not worth while. Do not, on the other hand, attempt to bring about an overlearning of everything.

(3) As you teach various subjects, teach efficient ways of studying in order that the material learned may be retained as well as possible. If you train children to recite their lessons to themselves, to avoid cramming and to spread their learning over a considerable amount of time, to use a "whole" method of attack in cases where such attack seems warranted, and to review systematically and selectively, you will be building up resistance against the oncoming tide of forgetfulness.

(4) Always try to organize knowledge so that children may see sections of the subject matter as being composed of related units. The better you and the children can organize what is to be learned, the better will be the resulting retention.

(5) Let children participate in their own education in so far as they are able to do so. They are more likely to remember the solution of problems they originally thought out for themselves than those that were solved for them. Self-activity is an aid not only to learning but to remembering."

(6) Do not expect a 100 per cent retention! Rare indeed is the course of study in which there is not much worthless material. If the children you are teaching seem to be forgetting too much, examine the course of study before blaming either them or yourself. The human animal is too intelligent to remember what is utterly without significance to it.

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Types of Films in Engineering Education*

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The emphasis and publicity given to the use of motion picture films and other audio-visual aids during the war by the Army, Navy, the United States Office of Education and others, has led to the suggestion that this Conference on Educational Methods might well consider and view some of the modern educational motion picture films in our field.

Three films were chosen for tonight's showing because I believe they represent the three basic types of motion pictures available for engineering instruction. Maybe this is an over simplification but by and large most engineering films fall into one or possibly a combination of two of the three following classifications.

Survey Films

First, is the survey type of film which attempts to give a general survey of a particular field; to demonstrate some broad principle or illustrate a general process. An example is an excellent film made by the United States Office of Education entitled "Powder Metallurgy." It makes no attempt to go deeply into any theoretical aspect but shows the general application of the powder-metallurgy technique to various manufactured products. Many films now available for engineering classes are of this nature. A few titles suggestive of this type are:

Principles of Lubrication,
Principles of Refrigeration,
The Electron,
Principles of Gas-Filled Tubes,
Energy and Its Transformation,
Thermodynamics,
Theory of Flight,

and many of a similar nature. These films serve excellently as an introduction to the subject and might very well be used during the opening lecture to give students a broad vista of the field to be covered. Many of our engineering teachers, quite adept at proving mathematical and abstract concepts, have difficulty in painting word pictures. These introductory films, therefore, should be welcomed by both the student and the instructor.

Films of this type can also be used to augment if not supplant inspection courses such as "Shop Trips" or "Plant Visits" which are normally included in most of our engineering curricula. This type of activity has been greatly curtailed during the war but I am sure that we will want to resume these courses as soon as possible. Motion pictures, however, can be and have been used very effectively to put over the same type of instruction. Films on the manufacture of steel,

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or glass, or the making of pipe, or a host of other products are available mostly, through the promotional efforts of commercial firms involved. Regardless of advertising matter, these films present a consecutive, logical and clear cut story which is far better than the usually incoherent, disorganized presentation of the so-called guide that often takes groups of students through plants. Besides, on such trips the student's attention is not always directed and held to the point in discussion. Those of you who have taken groups on field trips have often realized that unless the group is very small, the outer fringes have a tendency to disappear and investigate irrelevant details or extraneous items of their own choosing such as, for example, an attractive red-headed stenographer. The camera focuses attention and forces the student to follow the story.

I am not suggesting that films may completely supplant shop trips. A student should get the feel, smell and the noise of the wheels of industry in motion. He should actually be taken to see a number of manufacturing plants especially in the field of his major interest but these, however, might be limited possibly to an extended trip over a period of a week, perhaps during the Spring vacation. They could then be augmented by weekly presentations of survey films especially selected to cover the type of plant which would not be found convenient in the neighborhood of the engineering college involved.

Technique Films

The second type of motion picture is the film that illustrates or instructs in a specific technique. Such films are difinitely of the "how-to-do" character. Vast numbers of films of this nature have been developed especially during the war. Some of specific interest to the engineer are

Flue Gas Analysis—Orsat Apparatus,
Tension Testing,
Rockwell Hardness Testing,
Measurements by Use of Light Waves,
The Use of Slide Rule,
Heat Treatment of Steel including Hardening, Tempering, Annealing,

and a host of films of a general vocational or technical institute level in such fields as

Refrigeration Service,
Woodworking,
Foundry Practice,
Pattern Making,
Electrical Wiring,
Sheet Metal Work,
Aircraft and Shipbuilding Techniques,
Machine Tool Work,

and the like. I should not fail to mention at this point the excellent films on Drawing Room Practices and Techniques developed by Professors Boerlin and Rising, at Pennsylvania State College and Purdue University respectively.

The advantages of this type of film are obvious. Any of you who have attempted to give instruction in techniques to a whole room full of students realize how difficult it is to get the niceties of a technique over to all, especially those in the far corners of the room. For example, if you have had to attempt to illustrate to six or eight students grouped around you the operation of an Orsat apparatus you will appreciate, I am sure, the convenience of being able to show on the screen in twenty minutes the complete technique in detail.

It might be well to discuss at this point, the use of film strips to augment

the motion picture films themselves. One of the difficulties in the classroom use of motion pictures is that it is not possible to stop at any one particular point to stress or emphasize a specific action on the screen. A technique used very effectively by the United States Office of Education in the preparation of their war training films, has been the development of a 35 mm. film strip to accompany each film. This strip is most frequently made from shots taken directly from the movie itself. This, therefore, allows a flash back to an action which can be further discussed and elaborated on by the instructor if necessary. Thus the film is reviewed in abstract by the student and any questions that arise may be answered. The film strip is, of course, merely a modern counterpart of the lantern slide.

At New York University we have made very effective use of both the film and the film strip on flue gas analysis. At the opening introductory lecture in mechanical engineering laboratory the film entitled, "Flue Gas Analysis," is shown to the entire group. Later as each individual laboratory group comes to the experiment involving the use of the Orsat apparatus, the film strip is shown on a small screen provided in the laboratory and the film is reviewed just before the student actually performs the experiment and makes use of the Orsat apparatus.

The extension of the use of this technique type of film into other fields is also possible. For example, one available film entitled, "An Introduction to Vectors," develops a mathematical technique—the graphical and analytical addition of vectorial quantities. This is an extension of the "how-to-do" type of film to a field not involving manipulative skill. Additional films of this character, are contemplated.

Incidentally several of the publishers of technical textbooks have become keenly interested in the possibility of developing films of this type to go along with certain engineering texts such as Engineering Drawing.

Teaching Film

The third type of film is one which is relatively rare. Such a film definitely attempts to teach a new concept or principle in engineering. Films which are illustrative of this group include "Principles of Moments" and "Principles of Gearing." There are undoubtedly some others of a similar character but not, I believe, in large numbers. The reasons for the paucity of this type of film are that they are very difficult to conceive and require the most careful preliminary study, research and development before they are put into production. In addition, the actual production costs of these films are relatively high. The reason is that, in most cases, this third type of film requires almost one hundred per cent use of animation. The first group of films (the survey film) consists almost entirely of photography with incidental animation and is the cheapest to produce. Films of this type in lots of ten or so, were produced for the U. S. Office of Education during the war at a cost of about $6,000 per film of 600–800 feet (16 mm.) length. The second group, the technique film; which usually have an equal amount of photography and animation, cost about $8,000 per film. While the third group consisting usually almost entirely of animation cost about $10,000 per film of approximately 20-minutes playing time.

The first group of films, however,

appeals to a relatively wide group of purchasers. It would include not only engineering colleges but various industries which might be interested in having these survey types of films for plant training; or to adult education groups, or even to high school science classes. The market, therefore, is relatively broad, thus making for relatively low unit costs. The second type of film, the technique or "how-to-do" film, might sell to a somewhat more restricted but nevertheless fairly wide market. For example, the Orsat apparatus film would be of interest not only to the engineering colleges but would very probably be purchased by oil-burner manufacturers and other service organizations whose employees might be required from time to time to make a combustion test. The third type of film and the most expensive, however, appeals to a very limited group, the engineering college only. There are approximately 170 engineering colleges in the U. S., but just as no one text book will completely meet the needs of every college, it would not be possible to sell any one engineering film to any more than a very optimistic figure of 50 per cent of the colleges. Thus, the cost of production of the master film of the third type would have to be divided by about eighty sales, and would amount to approximately $125 per film. Adding to this the cost of the manufacture of the copies, plus even a limited cost for distribution, each film would probably have to sell to the college at the relatively high price of $150 to $200 per 600 feet of 16 mm. film of 20 minutes playing time. It is obvious, therefore, that a wide program of the third or teaching type of film on the engineering level cannot be developed on a commercial basis.

Although several schools, have attempted to meet this situation by making their own films, the results are not entirely satisfactory. Such schools as Purdue University, Pennsylvania State College and others have made contributions to the field of engineering education by means of films, but they usually have been produced by special funds to meet specific needs within the institution itself. Many of the films that have been so developed, valuable as they may be, have lacked professional polish which has somewhat limited their scope and appeal. In order that any film be as effective as possible, it is necessary that professional motion picture producers be employed to actually make the films. They should, of course, be constantly subject to check and consultation by a carefully selected group of technical advisors including not only engineering educators, but experts in the specialty involved as well. These men must see to it that the professional motion picture producer doesn't run away with the show, as was so frequently the case in some of the excellent techni-color movies made for the Army and Navy, which many engineering educators feel were brilliant movie cartoons of amusing interest but of questionable educational value professionally.

All of this may very possibly suggest a plan of action for the Visual Aids Sub-Committee of S.P.E.E. If we believe in the premise that the use of audio-visual aids will be of benefit to engineering education, permitting better and quicker teaching of certain standardized phases of our subject matter, and freeing time for more creative work, then we should begin by promoting actively the use of these audio-visual aids. That would require first bringing to the attention of all engineer-

ing instructors all of the aids now available. This is no easy task since there has been no organized development of visual aids in engineering education. The work that has been done in this field has been sporadic and by a number of different organizations and agencies. The first thing to be done is to investigate thoroughly and prepare a listing of all engineering audio-visual aids from any and all sources, Army, Navy, governmental agencies, promotional departments of industries, trade organizations, professional societies, schools, colleges, libraries, etc. Each of these listings should be accompanied by a brief description and "critique" giving an analysis of the visual aids type, its usefulness and its general level of approach, as a guide to the engineering instructor. This unbiased service backed by the prestige of S.P.E.E. should then be kept up-to-date by issuing from time to time new listings and "critiques" as required. Such a listing would serve to show the gaps in present material and suggest new fields of development of visual aids.

Obviously such a program can only be handled by a paid secretary. All of the committee members are anxious to serve and assist but they do not have time for this detail work, interesting as it may be to them. In addition to this catalogue, the secretary could develop research projects into class audience reaction, study the effectiveness of the various types of audio-visual aids and eventually develop more of the teaching (or third) type of film.

Certainly some source for subsidizing such a program could be found amongst the many philanthropic education foundations, the Motion Picture Association, or equipment and supply manufacturers. I trust this suggestion will present a challenge to the newly elected officers of this Division on Educational Methods and its sub-committee on Visual Aids.

Some Modifications in Approach to Teaching Engineers*

By E. C. SHUMAN

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The subject of teaching techniques as applied to professional engineers has been talked about and written about for such a long time, with apparently little effect, that it is obviously in the same category with Mark Twain's comment on weather. Basically, there is no good reason for my believing that anything I have to say will improve the situation. On the other hand, the need for improvement has been increasing so alarmingly, according to my observations, that I could not conscientiously refuse Professor Lilly's invitation to take part in the discussion. Since I have been each part of the triangle, studying, teaching, and practicing professional engineering at various times and under various conditions, I felt that I was qualified to express an opinion here.

Since this discussion must of necessity be short, can cover only limited emphasis, and will suffer from the dangerous practice of making general statements, I am sure that in some cases my intended meaning will be misunderstood. So that at least the over-all intent will not be misunderstood, what I have to say is not intended to be complimentary to the general methods of teaching engineers today.

It seems to me that more progress in teaching methods has been made in recent years in the better elementary schools than in the colleges. There seems to be too prevalent a feeling on the part of college teachers that all of the fault lies in the preparatory schools. I feel that there is room for major improvements in teaching methods at all educational levels. The method of measurement of educational attainment constitutes a difficult problem in itself, yet the difficulty is no reason for disregarding it entirely. In a similar vein, the fact that almost no attempt is made for quality control of teachers' teaching ability is no reason for supposing that such a procedure would not be advisable.

The selection of teachers on the basis of teaching ability seems never to have been considered important. If management in industry considers selection of foremen on the basis of leadership important, and uses methods to accomplish such selection, surely college administrators can use similar approaches in selecting teachers who can inspire accomplishment in students.

There seems to be general acceptance of the idea that if one is to sell anything over an extended period of time, a standard quality must have both producer and consumer acceptability. Since the public, as a consumer,

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is being sold on the idea that its welfare is dependent upon responsible professional engineers, as exemplified by general licensure for the profession, there must be some assurance that quality of instruction is commensurate with the standards of content of approved curricula. Surprising as it may seem, neither engineering accomplishments nor advanced degrees are of themselves assurance of high quality of instruction. There is evidence in some schools that they do have advertising value. In fact, there seems to be more evidence that engineering accomplishment and advanced degrees are more liable to be conducive to poor teaching rather than good teaching. High quality of instruction is not simple to define, but it seems to me to involve more than a parrot-like repetition of facts. It must be a mental "at-one-ment" of the instructor and the student to an awareness of their ultimate social responsibilities. This is definitely a part of a professional approach to the education of engineers as much as the dissemination of technical facts. If our future professionals have not been taught more than technical information, then the future of the world looks black indeed. I hope that some forces more noble than personal selfishness soon gain superiority. But from a realistic viewpoint, the modifications must come from within the profession voluntarily. The individualism of the engineer must give way to cooperation between engineers, if for no other reason than self defense. With the advent of labor unions into the ranks of college teachers and also students, the approach of teaching engineers requires drastic revision if engineering is to maintain a semblance of professional standing. Due to petty jealousies, with or without cause, between instructors in a department, instructors in different departments, administrators and executives, such revision at present seems practically impossible. As a consequence, it is probable that our chunk system will get much worse before it gets better. The chunk system is the one most commonly used, in which each course is given as a chunk of learning, with little or no attempt at correlation with professional engineering as a whole. An immediate sweeping revision in method is not the best solution, but an appreciation of the value of specific educational ties between even the basic courses is essential to a major improvement in methods. Such ties, forward, backward, and laterally, by planned references accomplish more toward educational progress than might be supposed, unless one has tried it. Of course, the young instructor must have enough freedom to use such approaches.

There seems to be little logic in teaching a student by chunks, in 50 minute periods with a "take 10" between, where he acts as an individual for 4 years (more or less), and then have him step into a job where he works as a part of an integrated organization, as a part of a small group, where his work is a continuity during the hours which are prescribed. I do not mean to imply that colleges should operate continuously on an 8 hour day. It is true that in some "working" courses, such as surveying and laboratory exercises, group action is undertaken, but in the "thinking" courses, which are the bases of engineering planning, we often find an instructor reading parrot-like from his notes which he took as a student, which his instructor took as a student, which his, etc.,—or else have had no recent

revision. Everyone knows of the partial obsolescence of a book the day it is published. Surely you have heard of young graduate engineers who took engineering text books with them in this war, only to find them useless, because more advanced methods had been developed. Yet one seldom sees references made in class to engineering improvements as found in current periodicals. Certainly, all such items cannot be covered, but even the occasional ones serve to instill in students an appreciation of the continual changes for which they must be prepared.

One needs to compare college level instruction with the well known "Underwriters' Knot" procedure of the recent W. M. C. program of Training Within Industry to see that there is more than passing significance to the cliché that if the student has not learned, the teacher has not taught. To "tell" is not enough, and neither is to "show." Good instruction goes beyond both of these procedures. The real need for grading and "flunking" notwithstanding, there is good basis for a tax or tuition paying parent to expect his children to be taught adequately to the completion of a curriculum. Whether or not there has been an overemphasis on the value of a college degree for everyone is beyond the scope of this discussion.

To be more specific, when I was a student, there was strong admonition that one of engineers' greatest weaknesses was a profound lack of ability to write and speak effectively—that reports were an engineer's means for presenting facts. I believed the criticism then, and am sure of its validity now. Since there has been almost no improvement in approach to the subject of engineering English, there has been no improvement in the result, as found in recent graduates—and some not so recent. Specifically, superfluous or ambiguous words, and omission of pertinent facts have detracted more from the value of both interim and final reports than any other errors in engineering writing. Lack of differentiation of facts and opinions, and incoherence have detracted more from the compensatable value of engineers than any other errors in speaking.

In the brief examples of teaching techniques used and cited hereafter, I claim no originality insofar as date of first use is concerned. Moreover, I am sure other better ones have been or could be devised, but I feel that in this short discussion only examples in which some experience has been gained should be mentioned.

My first experience with the effect of method of teaching occurred over 20 years ago, when, in a "Materials of Engineering" course, I used moving pictures in some classes and not in others. Students who had seen pictures had a better grasp of the subject than those who had not. I realized that this was due largely to an aroused interest in the student as evidenced by the nature of the questions asked after each picture, whereas questions seldom were asked after a lecture. It seemed that interest was aroused by the pictures by giving the materials being studied a living function in the students' minds, which could scarcely be engendered by reading and listening to facts alone.

This experience made me wonder whether or not basic subjects could be made interesting, even though they had little apparent application to the glamor of engineering. To carry forward the basic approach of facts and interest, I adopted for myself the thought, "Stress the Fundamentals."

This came about by observation of other instructors, who, in attempting to modernize, went so far as to create the feeling that they were merely trying to impress someone with extensive knowledge. A *small* amount of such an approach is justified for arousing interest, but it rapidly becomes dangerous because it is "over the students' heads," and creates false impressions in them.

If the writing of good reports is admitted to be a necessity for engineers, I contend that it is better practice to write a few good ones than more mediocre or "fill-in" reports. In a laboratory course involving 10 to 12 experiments, the class was divided into groups of 3 or 4, with one student assigned as chief engineer for each experiment. The chief engineer was reponsible for the conduct of the test and the writing of the report, with complete copies for each member of the group, including blueprinted drawings (or other duplication).

In the "computation period," all members of the group performed some phase of the preparation of data as assigned by the chief engineer, usually including final tabulation and the plotting of graphs when required. In this way, each student became intimately familiar with the data, took part in the discussion that ensued within the group (and, surprisingly, between groups), and had a complete set of reports for his file at the end of the course without the painful "all-night report session" every week. There was little doubt in my mind that, under this system, students had a better insight into how reports are really prepared, and had better opportunity to write good reports because they had more time available. Since different opinions on the way reports should be written are prevalent, and rightly so, in order for the future chief engineers to become familiar with the expected form of report, the first experiment, which was simple and brief, was conducted for the whole class and each student wrote a report. The system of group activity aroused such an interest in accomplishment by each student, that I tried it in non-laboratory courses.

As mentioned briefly in the introductory remarks, I have a feeling that students, once accepted, have an inalienable right to as much education as they can absorb (within some time limit of minimum attainment). Obviously, some students are "better" than others, which may be due to several reasons other than difference in ability. If one admits that the better students eventually become the leading engineers, and, in general, I believe this is true, then the training in leadership for these better students constitutes a real part of *their* education. I base this contention that the "better" student deserves special consideration to prepare him for the role of a true leader on the bromide, "He knows his stuff, but he certainly can't pass it on," which applies to practicing engineers as well as instructors. Unfortunately, we find some in both walks of life who are actually afraid of telling underlings all they can or should.

Our whole educational procedure is based on a philosophy of teaching people how to get ahead of one another instead of how to get along with one another, a procedure to which I do not subscribe. Getting along with one another and fair competition are fully compatible, in my opinion. So I used group activity to let the better student learn something more than cold facts, that is, by helping others. In this way, good students helped the poorer stu-

dents to learn more usable facts and to accept sincere help from others graciously. Specifically, this was accomplished by assigning the working of problems in class to a group, with the chief engineer giving the "recitation" at the blackboard with the privilege of calling on the "consultants" (the other members of the group) for help. This served to accomplish the following: poor students learned more facts, and they learned how to think more clearly (which put them on the road away from "poor" students); good students did not learn any less facts because they would have to go at the same speed as the class anyway, but in addition they learned how to help others, and thereby strengthened their ability to identify and correct illogical thinking.

There is evidence of significant magnitude that the system of segregating students according to ability and having the class of "better" students do more work is definitely unpopular and does not accomplish the purpose intended, that is, produce better engineers.

Little has been done about the incorrect emphasis on "answers." For various reasons, all problems in school have answers. This makes good handbook engineers, who stick numbers into formulas and crank out "answers." Obviously, all practicing engineers use handbooks to some extent, but principally as reference books. After all, formulas are nothing but the shorthand of engineering. Some of you will agree with me that many engineering problems do not have answers in the usual sense, otherwise there could not be so much disagreement and difference of solution. To teach validity for differences in "answers" is difficult, but it should be done, and can be done.

For example, in a highway class one usually finds problems in location. Here, again, individual solutions do not give perspective to students, and make unnecessarily hard work for the instructor who intends to give constructive criticism. A typical problem in highway location was assigned, and a contour map, and pertinent data on population, industrial activities, etc. of the towns shown, was given each group, and these groups prepared solutions. The instructor prepared the same map with white ink on black paper to throw the image (reflectoscope) on the blackboard with white lines. Each chief engineer could draw his solution over the image and explain the reasoning behind his solution. By erasing the chalk marks of the one analysis, the same map was ready for the next. The discussions, which frequently grew into heated arguments accomplished several things, not the least surprising was that frequently only those members of the class who had to attend other classes in the next period left when the *second* bell rang. I am emphasizing here that a respect for different legitimate solutions was awakened, and an appreciation that "someone" must make the final decision, that the "someone" is responsible for the decision, and those under him must accept this decision graciously, regardless of whether or not they agree with it completely. The approach for the student in this apparent confusion is that differences of opinion must be kept in the book of experience, so that when the student becomes the "someone" who makes decisions, that his attitudes are not the same as those he criticized as a subordinate.

It may seem that I am leaning toward expanded curricula, and I do not object to the basic reasoning for the lengthening of an engineering curriculum from 4 years to 5 or 6, but I am sure that improved teaching techniques

will produce better engineers in 4 years than the chunk system in 5.

Moreover, I do not see how better engineers can be developed who can use sound judgment when they have been subjected for 4 of their formative years to the vicious system of grading "to a curve." Anyone who is even vaguely familiar with valid statistical methods knows that gross errors are almost certain to occur when the general relationships of a large history of data are applied to limited specific data. Obviously, the "grading curve" is almost certainly wrong when applied to a given class, or even to all classes of a given year.

While no measurements have been taken in the examples cited, which prove much to those who are satisfied with present methods or approaches, it is interesting to note a few comments from recent graduate engineers in the armed forces of the United States, written in letters to me at least a year ago from overseas.

"The one thing I perhaps remember best is your repeated phrase, 'Stress the Fundamentals.' That phrase, as I think back, indicated a lot of things. For one thing, I think it indicated that you were trying to instill in us a philosophy of the profession and not just trying to cram into us a lot of facts. It meant that our schooling should be a comprehensive whole, made up of a lot of interdependent facts with a real and honest philosophy underlying it all."

"Speaking of comprehensive wholes, we have too many socially irresponsible technicians and too few fully educated professionals to represent the engineers in a society sorely in need of men who can grasp and solve the intricate problems of that society in an unprejudiced and analytical manner."

"Engineering education is sorely lacking in something. I think it is that lack of a feeling of social responsibility. Engineers seem to be taught 'to Hell with that stuff.' They are taught how to build a highway, and not to give a tinker's dam why it is built, where it should be built, and who should use it, or how it affects the people living near it."

"A student engineer ought to be made to understand that the same world in which he will build his roads and factories is the same world in which there are wars, famine and intolerance, and he should be made to realize that, as a professional man, the abolition of intolerance is as much his domain as the abolition of a 10 per cent highway grade."

"Stress the fundamentals. That means the fundamentals that will enable us to use good judgment in designing wood trusses, in calculating the proper mix on a concrete job, in using dump trucks or carpenters to best advantage, in making the best use of one's leisure time, in influencing other people, or in voting for a sheriff or a President."

"As I look back, I can remember learning some facts. It was all very nice; I enjoyed it. I felt that I'd learn that stuff all over again sometime in the dim future. It never occurred to me that *that was it;* that sometime in the dim future I should *go on from there.* The student is not awakened from his pleasant dream that his life lies in the future and that all he is doing now is collecting a few facts that can be brushed-up to pull in the dough later on. He is not made to realize that he has already entered his profession and that that profession is not a means of making money in an enjoyable way, but a vehicle for serving people who will someday be depending on him for guidance, understanding and leadership."

I do not mean to imply that the administrators of our engineering courses do not have complex problems. I am fully cognizant of one in particular, and, that is, course content. I have

seen and heard representatives of industry request that standard curricula be revised to include this, that, and the other course. I submit that in most cases these requests, as applied to the undergraduate school, reflect only short-sightedness on the part of industry. Such requests come because an inadequate research program has been underway in the plant or industry, which results in a desire to catch up to competition quickly, plus a lack of honest appreciation of undergraduate attainment. Specifically, it is not appreciated by many administrators in industry that a student who has taken "a course" does not have a working knowledge in that subject, and, frequently, not even sufficient basis for expressing a qualified opinion. Those who hire young engineers without having a proper evaluation of their training, expect unreasonable things, to their own detriment, and do not realize that for some years after graduation a period of "engineers in training" must occur.

It is difficult to summarize the thoughts I have on the subject of an approach to teaching engineers because I have mentioned only a few points and those very briefly. However, I do know from experience that a different approach from that usually used today does produce results. This different approach should, of course, start in the elementary schools, and involves student interest in his subjects, himself, the better things of life, and appreciation—of his social obligations; of the detriment to himself and his fellowmen of personal selfishness; of the significance of his knowledge as a tool for doing good, that the tool becomes dull and needs resharpening; that he must contribute to the advancement of truth because truth is knowledge; that, basically, that there is a different mental attitude in a professional engineer and a technician that will produce a better world.

To my mind, good teaching technique depends on mental attitudes. Years ago I heard Knute Rockne point out that the difference between dirty playing and hard playing was principally mental attitude. I do not expect you to accept my methods as I have related them, but regarding improvements in approach to teaching engineers, what about *your* mental attitude? I have to work with what you produce.

Methods of Achieving Professional Recognition*

By WILLIAM F. RYAN

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Before seeking professional recognition for engineers we must first establish the thesis that engineering is a profession and not a trade. There is nothing invidious about the distinction. It does not imply that the engineer is any "better" in the sight of God or man than the carpenter, the plumber, or the operator of an automatic machine. It does imply however that his vocation is on a higher intellectual plane, and that his work is not subject to any standardized measurement of production or value. By education he has acquired greater knowledge of science and the arts than the tradesman, and by training and practice he has acquired the ability to exercise independent judgment and discretion in the application of that knowledge. In short, he has equipped himself to render a greater service to his fellow men.

I believe I can proceed on the assumption that this thesis, "Engineering is a Profession and not a Trade," will not be challenged in this company. I cannot believe that you are proposing that thousands of boys, possessing the keenest young minds in our nation, should spend six years in institutions of higher learning to learn a trade. I warn you they will not do it. If, through our own blindness, engineering degenerates into a trade, boys of the type who now study engineering will transfer to the pure sciences, to business administration, or to some other opportunity for higher service, and we shall never again be able to bridge a gap such as that which existed between the laboratories of Berkeley and Chicago, and the destruction of Hiroshima.

Irrefutable as this thesis may seem to us, nevertheless it has been challenged and is being challenged by people of too much importance for us to brush aside. It has been challenged by some employers, by many politicians, and by many of the brilliant young intellectuals who administer our labor laws. Worst of all, by their conduct and mental attitude, their own professional status is challenged by many engineers!

It is challenged by young engineers who come out of our colleges and voluntarily join a trade union. In their basic philosophy of restricted production, three men to do the work of one, standardization of function and standardization of remuneration, the trade unions, as we know them, are so far from the engineer's conception of his function in life, that no man with a knowledge of the facts and a real conception of professional obligations could consider alliance with them. The modus operandi of the American trade union is as foreign to professional conduct as the Nazi Gestapo is to the nor-

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mal processes of democratic government. Any major movement of engineers into trades unions is professional suicide.

The appeal of the trades unions to engineers can be successful only in the case of ill-instructed young men and of older men who have failed in their vocation. In most cases they have failed because they have not applied a professional concept to their engineering work. The young men we can do something about. The recruits are still in your hands. They can be sent into industry with a genuine sense of professional obligations and the means of achieving professional recognition. This is your task. No more urgent problem lies before you. I know it will be solved and quickly.

The greatest obstacle to our professional recognition is probably the older men who are not failures, but who, on the contrary, are acknowledged leaders of our profession, who nevertheless by their mental attitude and conduct do most to challenge the thesis that engineering is a profession. These are men whose own personal recognition is secure, won in days of really free enterprise, but who refuse to recognize the problem of young men starting their careers under present conditions. Their group consciousness, so far as it exists at all, is confined on the one hand to the élite of the profession, or on the other hand is so broad that it would include every American whose interest in engineering is sufficient to desire standardization of bolts and nuts: "Anyone with a legitimate interest," as it has been expressed. This would undoubtedly include the garage mechanic. It would probably include the modern housewife, whose problems with household appliances give her a "legitimate interest" in engineering.

In spite of the valiant efforts of Engineers' Council for Professional Development and other agencies to promote clear thinking on this fundamental concept of engineering as a profession, many of our recognized leaders think of engineers as a heterogeneous group, and engineering as an amorphous abstraction. Only a few months ago a committee of eminent engineers made a recommendation to the Executive Committee of a Founder Society. The recommendation may have been wise enough, but the reason assigned by the majority of the committee was "There is no generally accepted definition of a profession or of professional employment."

There is, of course, no lack of definitions of profession or of professional employment. They were defined, fundamentally, by the American Medical Association before most of us were born. They have been defined technically, for engineers, by the laws of 47 states, and they have been defined comprehensively and authoritatively by Committee on Professional Recognition of the Engineers' Council for Professional Development. These definitions, quoted from the 1945 annual report of E.C.P.D., are appended to this article.

Nevertheless, our committee of eminent engineers may be right when they say there are no *generally accepted* definitions of a profession or of professional employment. I submit then that the first step in achieving professional recognition is to secure general acceptance of these definitions. Again we must begin with acceptance by the engineers themselves, and again the recruits are in your hands. They must come out of our schools with a knowledge of the attributes of a profession and the obligations of a professional practitioner.

The technological excellence of our engineering schools is so high that I used to wonder what you gentlemen talk about when you gather to consider its improvement. I perceive, however, that you find plenty to talk about that has nothing to do with technology. The pages of your JOURNAL were recently enlivened by the query "Are You Teaching the Engineering Facts of Life?" * Well, are you? The author wanted to know if your boys are learning about labor unions for engineers. I can answer that one. They are learning a lot about the National Federation of Technical Engineers, Architects and Draftsmen's Unions, affiliated with the A.F. of L., and they are learning it from the Union itself. I have here one of their bulletins which announces "Student Headquarters Local No. 500—Available to students in the technical phases of engineering and architecture who are actively enrolled in a school, college or university of recognized standing and for a period of apprenticeship thereafter. The student initiation fee is $3 and the dues 50¢ per month, payable four months in advance." Note that elegibility is limited to students in institutions "of recognized standing." You may wish to inquire whether your particular school is accredited by the A.F. of L., and if so, why.

The author asked pertinent questions as to what the boys are learning about legal registration as professional engineers or engineers in training. I will come back to that, but in the meantime, I wish to ask a question of my own. "Do your students know what a profession is?" I know that many of my contemporaries have only the foggiest notion. But are the new recruits, the leaders of the future, grounded in that essential concept?

Too many of us think of professional status only in terms of prerogatives, remuneration, and public esteem. Those are the fruits, not the roots, of professional recognition. If you will examine the E.C.P.D. Committee's definition of a profession and professional practitioners, you will observe it is almost entirely a matter of service, unselfishness and high ideals. Professional recognition flows only from the faithful discharge of those obligations and, without an understanding of this fundamental requirement, the pursuit of professional recognition is a hopeless quest.

There is nothing visionary or impractical in this idealistic concept. It is the keynote of the medical profession and is carried to such an extreme that the doctor foregoes all personal profit from his own medical discoveries or inventions because he believes such altruism is in the interest of public health. Yet the doctors are utterly practical about it. After declaring that public welfare transcends all consideration of personal profit, their Code of Ethics proceeds with two pages describing the doctor's obligation to his patients, and twelve pages describing his obligations to other doctors. Devotion of a profession to the public interest requires no vows of poverty by its practitioners.

While the engineer's work fulfills all the requirements of a profession as defined by the E.C.P.D.'s Committee, his personal conduct falls far short. First in the matter of group consciousness, which the E.C.P.D.'s Committee specifies as an important attribute of a profession; in some eminent engineers it is completely lacking, in others it is

* By E. A. Holbrook, JOURNAL OF EDUCATION, Vol. 36, page 155.

too narrow. It is confined to mechanical engineers, or to illuminating engineers, or may be even more restricted; for example, to designers of steel bridges or to teachers of thermodynamics. In other cases the group consciousness is much too broad; this is the school of thought which embraces "All having a legitimate interest" in engineering.* These are the engineers who have so much trouble in defining professional employment, and who are responsible for much of the haziness in the public mind as to just who are engineers and who are not.

Now a profession is not an abstraction. It is a group—a group of *professional men.* The engineering profession is a group of *professional engineers.* If the first step in achieving professional recognition is to grasp what a profession is, then perhaps the second step is to grasp the extent and the limitations of the group who constitute our particular profession. I submit that this group includes all professional engineers and that it includes no others except the young men in colleges and apprenticeships who are in training to join the ranks of the professional engineers. It cannot include people, regardless of their employment or their "interest" in engineering, who are not, and have no hope of becoming, professional engineers.

Who, then, are these professional engineers? This brings us to the final attribute of a profession, as defined by the E.C.P.D.'s Committee: It should have a legal status.

The profession of engineering has technically a legal status in 46 of our states, and in every province of Canada. But has it a legal status in the mind of the engineer? In Canada yes, very definitely. But in this country no, at least if we are to judge by the attitude and example of many of the acknowledged leaders of the profession. Yet before we achieve professional recognition we must accept this concept of legal status. We must regard a certificate of registration in the same light as we regard our college diplomas, which, after all, add nothing to our knowlege, but which certify to all and sundry that we possess a certain amount of it. The certificate of registration adds nothing to our knowledge, but it does certify that we know how to apply it.

Again we can profit by the Doctors' example. I do not know how many physicians may have opposed registration when the states first required it by law. Possibly some of the most eminent physicians were as scornful as many of our leaders are now, but the present day practitioner knows that legal registration is the chief bulwark of his professional recognition.

The final attribute of professional practitioners as defined by the E.C.P.D.'s Committee is: "They should be members of professional groups and they should carry their part of the responsibility of advancing professional knowledge, ideals, and practice."

So far as the advancement of knowledge is concerned, we are highly and effectively organized. If we were technicians or tradesmen, our organization would leave little to be desired, but we are professional men, and with respect to the advancement of professional ideals and professional practice, or the achievement of professional recognition, then our organization is the most cumbersome and ineffective one that the mind of the engineer could well con-

* See: "A National Spokesman for Engineers" by A. B. Stickney, JOURNAL OF EDUCATION, and numerous other publications, 1946.

ceive. Others might conceive a worse one, but not the engineer.

If I have wearied you with repeated references to the doctors, it is because they have achieved the professional recognition to which we aspire, the kind of recognition which permitted drafting a doctor into the armed services only on condition he was made at least a first lieutenant while engineers were being sent to boot camp as apprentice seamen. They have achieved the kind of recognition which kept our medical schools fully populated while engineering colleges were stripped of all but the physically unfit.

This kind of recognition was not forced upon the doctors by a grateful public. It was won by faithful discharge of professional obligations, and by intelligent organization, first to determine exactly what these obligations are, second to enforce their faithful observance, and third to secure the recognition to which the faithful discharge of such obligations is entitled. This organization is the American Medical Association, with its component societies in every state and territory of the United States, and with local chapters throughout each state.

The State Society is what the doctor joins and the organization to which he pays his dues, but membership in the National Society and a District Society follows automatically. It is in the District Society that he meets with other members of his profession for discussion of professional problems. There are eighteen of these District Societies in Massachusetts, each of which is a relatively small local group, interested in common problems, and united to work together for the benefit of the public in their community, and incidentally for the benefit of themselves as professional men. These several District Societies form the Massachusetts Medical Society. Similar District Societies in the 47 other states, all the territories and the District of Columbia combine with the Massachusetts Medical Society and with the representatives of the Medical Corps of the Army, Navy and Public Health Service, to form the American Medical Association. In this manner, every registered practitioner under the American flag is eligible for membership. Every doctor is united with every other doctor to maintain his professional interests in his own locality, in his state and in the nation. The delegates who govern the American Medical Association are elected, in numbers proportional to their membership, by the State Societies, and delegates are also appointed by the Medical Corps of the Army, the Navy, and the Public Health Service. The Association operates effectively through a Board of Trustees, several Bureaus and numerous Councils and Committees. Their avowed object is to protect the public in anything and everything that has a medical aspect, to oppose unwise legislation, to expose false remedies, to promote health habits, to spread medical knowledge and to establish standards of medical ethics. So far as I know, no other medical group concerns itself with such problems. While some doctors join one society and some another for technical purposes, they leave to the A.M.A., and to it alone, their professional and economic problems. Incidental to a genuine and invaluable public service, all the more effective because of fundamentally unselfish objectives, they protect all doctors individually and collectively, from any attack on their professional prerogatives, whether by Government, industrial or financial groups, or by individuals.

I am presenting the American Medical Association as a model of professional organization. Actually the A.M.A. sponsors technical activities as well. These are handled through the Scientific Assembly, and the member must pay additional dues if he cares to participate in that work. As with the engineer, however, the doctor has found a need for more and more highly specialized societies. Eighty-nine of them, on the national level, are listed in the latest medical directory. Technically, the medical profession is a victim of the same fragmentation which afflicts us, but professionally it has one group, one spokesman, representing all registered practitioners, and nobody else belongs. No nurses, no orderlies, no hospital janitors, no pharmaceutical manufacturers, not even unregistered holders of medical degrees.

How is the engineering profession organized for professional objectives, that is, to determine what its professional obligations are, to enforce the discharge of these obligations by its practitioners, and to win the recognition to which the discharge of these obligations is entitled?

At this moment only God knows how we are organized for those objectives. The Engineers' Joint Council, one of the most important elements in whatever organization we have, has a committee and three sub-committees trying to find out.

The latest issue of "Who's Who in Engineering" (1941) lists 71 national organizations as "engineering societies." All of them have engineers among their members, no doubt, and all of them have activities of technical interest to engineers, but of this group, judging by their names, only 40 should really be considered engineering societies and in only one is membership constitutionally limited to professional engineers. At least 30, either by their constitutional statement of objectives, or by their activities on the national or local level, appear to be interested in the professional status and economic welfare of the engineer, as well as the technical advancement of their own specialized branch of engineering.

The largest and most important engineering societies, while maintaining their own individual committees on ethics, professional conduct and economic problems, have joined forces for the study of professional problems in two major Councils, the Engineers' Council for Professional Development, and Engineers' Joint Council.

Fortunately, in this group, I do not have to explain what the E.C.P.D. is or what its objectives are. In other groups I have not been let off so easily. In fact, many lifelong members of the Founder Societies have yet to learn of the existence of E.C.P.D. or E.J.C.

You are also thoroughly familiar with the E.J.C. and its organization. Some of its objectives appear to compete with or overlap those of E.C.P.D., but no doubt there is a coordinating genius somewhere.

Both of these joint efforts are noble attempts to supply a great deficiency. If I am not over hopeful of their ultimate results, it is because by service on sub-committees of both, I am painfully aware of the general ineptitude of the setup. Nothing would seem more fundamental to professional unity than a common Code of Ethics, yet the Canons proposed by E.C.P.D. five years ago are still unratified. The sub-committee has received sufficient encouragement this year so that we are willing to try again, and we are not without hope of ultimate success, but this protracted delay in arriving at such a fundamental

objective illustrates one major defect in a league or coalition of sovereign societies.

Another defect of these Councils is their remoteness from the individual members of the sponsor societies. Members of the A.S.M.E. in Boston or St. Louis or Seattle are not conscious of having any influence on these Councils. They pay them no direct dues, they get no direct reports, they elect no delegates, in fact they represent "New York activities" of no particular concern to them.

On the local level, we have various attempts to combine our diverse technical societies for professional objectives. An outstanding example is the Engineering Societies of New England, Inc. Like most local coalitions, it is a heterogeneous group with hundreds of members who are not, and never will be, professional engineers. Nevertheless, the E.S.N.E. is closer to the individual member in Boston, and he feels that he gets more service from it along professional as distinct from technical lines than from the more ambitious Councils on the national level. The E.C.P.D. is now asking for local sections. If one is formed in Boston, it will probably be an activity of E.S.N.E. in spite of its heterogeneous membership.

Briefly, this is the engineering profession's organization for professional objectives: Twenty or more national societies each going its own way, five joining forces in one Council and eight in another, plus various regional and local coalitions with various degrees of engineering sponsorship. It hasn't worked. It can be made to work only by education and effort possibly beyond our powers, certainly beyond our powers to accomplish quickly. Nor am I hopeful of any of the more ambitious coalitions now being proposed. Actually, our problem of adequate professional organization is very simple if the trees did not obscure our view of the forest.

There is one society among the 30 or 40 or 71, depending on how inclusive you make the term, and only one, whose membership is limited to professional engineers. This is the National Society of Professional Engineers. It is a society organized very frankly in imitation of the American Medical Association, minus the Scientific Assembly. Its objectives are solely professional, leaving technical and scientific pursuits to the other 70 societies more or less, which are organized for those purposes. It is a relatively small group, at the moment, but is growing rapidly. It had 13,000 members at the end of March and is expected to have 25,000 before the end of the year.

There are now 22 component state societies, the larger ones divided into local chapters. Other state components are in process of organization. These state societies may have "engineers in training" as junior members and some have student branches, but only registered professional engineers are members of the national society.

The National Society of Professional Engineers has all the potentialities of the American Medical Association. It is organized along the same lines, for the same objectives, and with the same simple but definite rule of eligibility. Its potentialities can be realized, however, only when it has a representative membership, that is, when it includes the great majority of professional engineers, and substantially all of the acknowledged leaders of profession, many of whom are not even eligible

because of their scorn of legal registration. Educators are conspicuously absent from the membership rolls, in many states. They do not have to be registered and so they neglect this obvious opportunity to furnish inspiration and leadership to the young men who look to them for both.

The young men, however, are getting registered. They are more acutely aware of the problems besetting the future of our profession than many of their elders. The leaders of the future then will at least be eligible to join a society of this type. But events will not wait for these boys to mature. We must have immediate and constructive leadership from our present leaders. The young men are looking for that; let us not disappoint them. Let every one of us, from the college freshmen to the presidents of the Founder Societies, acquire a firm grasp of the meaning of a profession and its obligations. Let us develop a group consciousness, recognizing that our group includes all professional engineers and all candidates for that vocation. Let us accept in spirit as well as in law, the legal status which E.C.P.D.'s Committee has correctly named an indispensable attribute of a profession, and let us organize intelligently and effectively for these objectives. When these things are done, we shall achieve professional recognition.

New Members

BARTHOLOMEW, DAVIS, Assistant Professor of Electrical Engineering, University of Arizona, Tucson, Ariz.

BECK, WILLIAM M., Instructor in Engineering, William & Mary, V. P. I., Norfolk, Va.

BENECKE, ROBERT O., Head, Dept. of Engineering, Municipal University of Omaha, Omaha, Nebr.

BRESLER, BORIS, Lecturer in Civil Engineering, University of California, Berkeley, Calif.

BUTLER, EDWARD J., Assistant Professor of Engineering and Management, Thayer School of Engineering, Hanover, N. H.

CAPP, MARTIN P., Associate Professor of Civil Engineering, University of Denver, Denver, Colo.

CHAPPELLE, THOMAS W., Coordinator, Cooperative Plan, Assistant Professor of Mechanical Engineering, University of Denver, Denver, Colo.

COOPER, BYRON N., Head, Dept. of Geology, Virginia Polytechnic Institute, Blacksburg, Va.

DANNER, WALTER N., Professor of Agricultural Engineering, University of Georgia, Athens, Ga.

DWYER, ORRINGTON E., Assistant Professor of Chemical Engineering, University of Rochester, Rochester, N. Y.

ENG, SIDNEY A., Director of Industrial Relations, Milwaukee School of Engineering, Milwaukee, Wis.

HAMLEN, EARLE K., Assistant Professor of Mechanical Engineering, University of Akron, Akron, Ohio.

HETENYI, MIKLOS, Professor of Engineering Mechanics, Northwestern University, Evanston, Ill.

HOWARD, RUSSELL L., Instructor in General Engineering, Iowa State College, Ames, Iowa.

HRUBECKY, HENRY F., Instructor in Mechanical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

HUNTINGTON, RICHARD L., Director, School of Chemical Engineering, University of Oklahoma, Norman, Okla.

JOHNSON, JOE W., Associate Professor of Mechanical Engineering, University of California, Berkeley, Calif.

JOHNSON, ROBERT R., Graduate Instructor in Mathematics and Mechanics, University of Minnesota, Minneapolis, Minn.

KANE, ENEAS D., Assistant Professor of Mechanical Engineering, University of California, Berkeley, Calif.

LIN, TUNG Y., Assistant Professor of Civil Engineering, University of California, Berkeley, Calif.

MACKENZIE, DONALD H., Dean, Lincoln Technical Institute, Northeastern University, Boston, Mass.

MATLOCK, JOSEPH R., Director, School of Civil Engineering, University of Oklahoma, Norman, Okla.

MILES, HUGH S., Assistant Professor of Mechanical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

NELSON, CARL W., Assistant Professor of Mechanical Engineering, University of California, Berkeley, Calif.

PALMER, AUBREY E., Assistant Professor of Civil Engineering, Duke University, Durham, N. C.

PETRY, WILLIAM M., Assistant Professor of Mechanical Engineering, University of Akron, Akron, Ohio.

PHILLIPS, STEPHEN A., Instructor in Mechanical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

POLK, ORVAL H., Associate Professor of Electrical Engineering, U. S. Naval Academy, Annapolis, Md.

REHM, RICHARD W., Assistant Professor of Engineering Drawing, University of Toledo, Toledo, Ohio.

SAVORY, LEONARD E., Instructor in Chemical Engineering, University of Denver, Denver, Colo.

SAXER, EDWIN L., Assistant Professor of Civil Engineering, University of Toledo, Toledo, Ohio.

SELBY, SAM, Head, Dept. of Mathematics, University of Akron, Akron, Ohio.

SHAFER, BERKELEY R., Instructor in Engineering, Marshall College, Huntington, W. Va.

SHERWOOD, CALDER S., Assistant Professor of Chemistry, William and Mary V. P. I., Norfolk, Va.

SNIVELY, LLOYD C., Assistant Professor of Engineering Mathematics, University of Colorado, Boulder, Colo.

STINSON, SAMUEL T., Assistant Professor of Engineering, Marshall College, Huntington, W. Va.

THEAKSTON, HAROLD R., Professor and Head, Dept. of Engineering, Dalhousie University, Halifax, N. S.

THOMPSON, DUDLEY, Assistant Professor of Chemical Engineering, Virginia Polytechnic Institute, Blacksburg, Va.

WAGNER, STEPHEN S., Assistant Professor of Engineering, University of Buffalo, Buffalo, N. Y.

WEAVER, ERNEST W., Assistant Professor of Mechanical Engineering, University of Toledo, Toledo, Ohio.

WEBB, LEWIS W., Director of College, William and Mary, V. P. I., Norfolk, Va.

WERWATH, HEINZ M., Director of Admissions, Milwaukee School of Engineering, Milwaukee, Wis.

YOUNG, EARL R., Associate Professor of Agricultural Engineering, University of Kentucky, Lexington, Ky.

329 new members

Graduate Engineering Students, Enrollment, November 5, 1946, by Courses

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree												
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters' Degrees Conferred in 1945–1946			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors' Degrees Conferred in 1945–1946		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Aeronautical	356	—	141	115	1	90	39	—	41	510	1	272	140	—	2	9	2	1	8	—	—	5	—	3	22	2	4	2	—	1
Agricultural	22	—	20	23	—	8	—	—	—	45	—	28	5	—	—	—	—	2	2	—	—	—	—	—	2	—	2	—	—	—
Architectural	19	—	8	7	—	2	26	—	—	52	—	10	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ceramic	46	—	20	34	1	22	—	—	—	80	1	42	3	—	—	10	—	4	5	—	2	—	—	—	15	—	6	—	—	—
Chemical	916	3	583	442	12	295	352	3	186	1710	18	1064	204	2	18	110	2	28	136	1	48	31	—	7	277	3	83	26	—	1
Civil	507	1	256	226	—	141	192	—	163	925	1	560	126	—	12	49	—	4	41	—	21	8	—	22	98	—	47	16	—	1
Electrical	894	2	302	388	1	296	522	1	266	1804	4	864	182	1	9	70	2	4	49	—	20	11	—	6	130	2	30	15	—	—
Industrial	82	—	46	141	2	63	149	3	108	372	5	217	51	—	1	1	—	9	—	—	—	16	—	—	17	—	9	—	—	—
Mechanical	646	4	283	442	11	200	318	3	170	1406	18	653	178	—	3	87	1	12	17	1	1	22	—	13	126	2	26	10	—	1
Metallurgical	232	—	89	95	—	21	124	3	78	451	3	188	33	2	7	13	—	1	28	—	4	53	—	21	94	—	26	8	—	—
Mining	53	—	36	28	—	13	1	—	—	82	—	49	27	—	7	2	—	—	1	—	1	—	—	—	3	—	1	1	—	—
Unclassified	345	3	188	172	20	53	660	23	123	1177	46	364	80	—	9	50	—	15	13	—	2	4	—	—	67	—	17	4	—	—
Totals	4118	13	1972	2113	48	1204	2383	36	1135	8614	97	4311	1031	5	69	401	7	80	300	2	99	150	—	72	851	9	251	82	—	4

M. = men. W. = women. V. = veterans.

Graduate Engineering Students, Enrollment, November 5, 1946, by Courses—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree												
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters' Degrees Conferred in 1945–1946			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors' Degrees Conferred in 1945–1946		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Ala. Poly	—	—	15	—	—	—	—	—	—	—	—	15	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ala. Uni	6	—	26	—	—	—	—	—	—	6	—	26	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alfred	12	—	3	8	—	8	—	—	—	20	—	11	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arizona	4	—	2	—	—	—	—	—	—	4	—	2	2	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Brooklyn	88	8	101	459	39	336	104	10	43	651	57	480	71	2	—	159	8	26	38	2	16	—	—	—	197	10	42	18	—	2
Brown	7	—	7	6	—	6	—	—	—	13	—	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Buffalo	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14	—	—	14	—	—	—	—	—
Calif. Tech	337	—	—	—	—	—	—	—	—	337	—	—	138	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—
Calif. Uni	217	—	—	35	—	—	—	—	—	252	—	—	16	—	—	13	—	—	11	—	—	—	—	—	24	—	—	1	—	—
Calif. Uni. (L. A.)	24	—	18	—	—	—	—	—	—	24	—	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calif. Uni. So	23	—	56	—	—	—	—	—	—	23	—	56	2	—	1	—	—	—	1	—	1	—	—	—	1	—	1	1	—	1
Carnegie	29	—	53	4	—	9	—	—	—	33	—	62	23	—	4	6	—	—	21	—	8	64	—	68	91	—	76	3	—	—
Case	48	—	42	25	—	17	71	—	22	144	—	81	5	—	—	1	—	—	—	—	—	5	—	—	6	—	—	1	—	—
Catholic	—	—	—	1	—	—	22	—	—	23	—	—	—	—	—	—	—	—	—	—	—	3	—	—	3	—	—	—	—	—
Cincinnati	23	—	18	—	—	—	—	—	—	23	—	18	—	—	—	—	—	—	5	—	2	—	—	—	5	—	2	2	—	—
Colo. A. & M	3	—	—	1	—	—	20	—	10	24	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Colo. Mines	21	—	19	—	—	—	—	—	—	21	—	19	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Colo. Uni	5	—	74	—	—	—	123	—	150	128	—	224	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Columbia	—	—	—	349	4	261	—	—	—	349	4	261	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cornell	51	1	—	36	—	—	—	—	—	87	1	—	36	—	—	8	—	—	11	—	—	—	—	—	19	—	—	8	—	—
Delaware	22	—	15	—	—	—	38	—	35	60	—	50	2	—	1	1	—	—	3	—	1	—	—	—	4	—	1	—	—	—
Denver	4	—	3	—	—	—	—	—	—	4	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Columbia	—	—	—	349	4	261	—	—	—	349	4	261	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cornell	51	1	—	36	—	—	—	—	—	87	1	—	36	—	—	8	—	—	11	—	—	—	—	—	19	—	—	8	—	—
Delaware	22	—	15	—	—	—	38	—	35	60	—	50	2	—	1	1	—	—	3	—	1	—	—	—	4	—	1	—	—	—
Denver	4	—	3	—	—	—	—	—	—	4	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Graduate Engineering Students, Enrollment, November 5, 1946, by Courses—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree													
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters' Degrees Conferred in 1945–1946			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors' Degrees Conferred in 1945–1946		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Florida	—	—	3	4	—	11	—	—	—	4	—	14	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ga. Tech	69	—	64	35	—	18	—	—	—	104	—	82	2	—	1	2	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Harvard	83	—	159	7	—	7	—	—	—	90	—	166	42	—	11	6	—	3	4	—	1	—	—	—	10	—	4	6	—	—
Idaho	3	—	—	11	—	—	—	—	—	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ill. Tech	76	—	—	51	2	—	571	2	—	698	4	—	20	—	—	12	—	—	1	—	—	15	—	—	28	—	—	3	—	—
Iowa St. Coll	21	—	53	10	—	11	—	—	—	31	—	64	9	—	—	9	—	5	4	—	3	—	—	—	13	—	8	3	—	—
Iowa St. Uni	61	—	23	18	—	11	—	—	—	79	—	34	7	—	1	11	—	6	2	—	—	—	—	—	13	—	6	—	—	—
J. Hopkins	68	—	9	50	—	—	40	—	—	158	—	9	2	—	—	7	—	—	26	—	8	—	—	—	33	—	8	—	—	—
Kans. St. Coll	6	—	3	29	—	21	—	—	—	35	—	24	3	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kans. Uni	9	—	28	—	—	—	—	—	—	9	—	28	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Kentucky	2	—	6	—	—	7	—	—	—	2	—	13	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lafayette	—	—	—	—	—	—	7	—	—	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Louisiana	52	—	—	—	—	—	21	—	—	73	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Louisville	15	—	13	10	—	5	—	—	—	25	—	18	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Maine	16	—	12	2	—	—	—	—	—	18	—	12	3	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Maryland	1	—	2	55	—	100	2	—	13	58	—	115	—	—	—	—	—	2	—	—	4	—	—	—	—	—	6	—	—	—
Mass. Inst. Tech	803	—	—	—	—	—	—	—	—	803	—	—	167	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mich. M. & T	20	—	19	—	—	—	—	—	—	20	—	19	12	—	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mich. St. Uni	25	—	12	6	—	4	—	—	—	31	—	16	2	—	1	2	—	2	3	—	2	—	—	—	5	—	4	—	—	—

Graduate Engineering Students, Enrollment, November 5, 1946, by Courses—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree											
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters' Degrees Conferred in 1945–1946			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors' Degrees Conferred in 1945–1946		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Mich. Uni.	183	—	262	17	—	10	—	—	—	200	—	272	99	—	2	—	—	—	32	—	18	—	—	—	32	—	18	7	—	—
Minnesota	—	—	—	212	—	146	—	—	—	212	—	146	5	—	—	51	—	19	—	—	—	—	—	—	51	—	19	6	—	—
Mo. Mines	58	1	41	—	—	—	—	—	—	58	1	41	3	—	—	—	—	—	3	—	2	—	—	—	3	—	2	—	—	—
Mo. Uni.	24	—	18	—	—	—	—	—	—	24	—	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mont. Mines	16	—	—	—	—	—	—	—	—	16	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mont. St. Coll.	1	—	—	5	—	5	—	—	—	6	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nebraska	21	—	18	—	—	—	—	—	—	21	—	18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Newark	—	—	—	—	—	—	100	2	84	100	2	84	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
New Hampshire	—	—	1	1	—	—	—	—	—	1	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N. Mex. Uni.	3	—	3	—	—	—	—	—	—	3	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N. Y. C. C.	20	—	—	—	—	—	6	—	—	26	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
New York Uni.	52	1	55	—	—	—	238	4	213	290	5	268	32	—	1	—	—	—	5	—	2	40	—	4	45	—	6	—	—	—
N. Car. St. Coll.	47	—	—	—	—	—	—	—	—	47	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Northwestern	42	—	29	48	—	34	20	—	2	110	—	65	2	—	—	2	—	1	6	—	—	—	—	—	8	—	1	—	—	—
Notre Dame	7	—	27	—	—	—	—	—	—	7	—	27	—	—	—	1	—	—	—	—	—	—	—	—	1	—	—	—	—	—
Okla. Uni.	39	—	—	—	—	—	—	—	—	39	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oregon	45	—	—	—	—	—	—	—	—	45	—	—	4	—	—	—	—	—	3	—	—	—	—	—	3	—	—	—	—	—
Pennsylvania	66	—	40	15	—	4	232	1	131	313	1	175	20	—	—	21	—	—	6	—	1	—	—	—	27	—	1	—	—	—
Pa. St. Coll.	39	—	—	72	1	—	—	—	—	111	1	—	14	—	—	19	—	—	9	—	—	—	—	—	28	—	—	2	—	—
Pittsburgh	2	—	17	—	—	—	199	—	178	201	—	195	27	—	—	—	—	—	—	—	—	9	—	—	9	—	—	3	—	—
Princeton	49	—	—	20	—	—	—	—	—	69	—	—	—	—	—	1	—	—	14	—	—	—	—	—	15	—	—	—	—	—
Purdue	54	—	—	199	1	—	—	—	—	244	1	—	35	—	—	26	—	—	—	—	—	—	—	—	26	—	—	3	—	—

Pennsylvania	66	—	40	15	—	4	232	1	131	313	1	175	20	—	—	21	—	—	6	—	1	—	—	—	27	—	1	—	—	—
Pa. St. Coll.	39	—	—	72	1	—	—	—	—	111	1	—	14	—	—	19	—	—	9	—	—	—	—	—	28	—	—	2	—	—
Pittsburgh	2	—	17	—	—	—	199	—	178	201	—	195	27	—	—	—	—	—	—	—	—	9	—	—	9	—	—	3	—	—
Princeton	49	—	—	20	—	—	—	—	—	69	—	—	—	—	—	1	—	—	14	—	—	—	—	—	15	—	—	—	—	—
Purdue	54	—	—	199	1	—	—	—	—	244	1	—	35	—	—	26	—	—	—	—	—	—	—	—	26	—	—	3	—	—

Graduate Engineering Students, Enrollment, November 5, 1946, by Courses—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree													
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters' Degrees Conferred in 1945–1946			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors' Degrees Conferred in 1945–1946		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Rensselaer	81	—	60	71	—	52	46	2	23	198	2	135	12	—	1	1	—	1	3	—	—	—	—	—	4	—	1	—	—	—
R. I. St. Coll.	—	—	4	—	—	—	—	—	—	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rice Inst.	6	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rochester	21	—	—	11	—	—	—	—	—	32	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rutgers	—	—	—	26	—	18	—	—	—	26	—	18	1	—	—	6	—	4	—	—	—	—	—	—	6	—	4	—	—	—
So. Car. Uni.	—	—	6	—	—	—	—	—	—	—	—	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
S. Dak. Mines	7	—	7	—	—	—	—	—	—	7	—	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Stanford	291	—	—	—	—	—	40	—	—	331	—	—	25	—	—	—	—	—	22	—	—	—	—	—	22	—	—	5	—	—
Stevens	—	—	—	—	—	—	289	13	231	289	13	231	47	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Syracuse	17	—	2	1	—	—	44	—	—	62	—	2	—	—	—	—	—	—	2	—	—	—	—	—	2	—	—	—	—	—
Tennessee	72	1	17	—	—	—	16	2	—	88	3	17	1	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Texas A. & M.	91	—	—	—	—	—	—	—	—	91	—	—	13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Texas Uni.	135	—	103	33	—	18	—	—	—	168	—	121	10	—	—	13	—	1	9	—	5	—	—	—	22	—	6	3	—	—
Thayer	32	—	31	—	—	—	—	—	—	32	—	31	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tulane	4	—	4	—	—	—	—	—	—	4	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tulsa	7	1	14	—	—	—	—	—	—	7	1	14	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Union	—	—	—	—	—	—	134	—	—	134	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Utah Uni.	33	—	—	—	—	—	—	—	—	33	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vanderbilt	7	—	4	2	—	1	—	—	—	9	—	5	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Va. Poly.	75	—	69	10	—	—	—	—	—	85	—	69	10	—	3	1	—	1	1	—	1	—	—	—	2	—	2	1	—	—

Graduate Engineering Students, Enrollment, November 5, 1946, by Courses—Continued

Engineering Courses	Enrollment in Work for the Master's Degree															Enrollment in Work for the Doctor's Degree												
	Full-Time Resident Students			Part-Time Resident Students			Evening Students			Total			Masters' Degrees Conferred in 1945–1946			Part-Time Resident Students			Full-Time Resident Students			Evening Students			Total			Doctors' Degrees Conferred in 1945–1946		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Wash. St. Coll.	4	—	3	8	—	8	—	—	—	12	—	11	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wash., Uni.	19	—	92	24	—	10	—	—	—	43	—	102	7	—	—	2	—	—	1	—	1	—	—	—	3	—	1	—	—	—
Wash. U. (St. L.)	30	—	25	53	1	30	—	—	—	83	1	55	3	—	1	2	—	2	6	—	3	—	—	—	8	—	5	—	—	—
Wayne	2	—	2	29	1	13	—	—	—	31	1	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
W. Va. Uni.	—	—	—	1	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Wisconsin	21	—	66	9	—	10	—	—	—	30	—	76	12	—	—	6	—	1	8	—	5	—	—	—	14	—	6	1	—	—
Wyoming	4	—	14	—	—	—	—	—	—	4	—	14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Yale	63	—	52	16	—	8	—	—	—	79	—	60	7	—	1	11	—	6	28	—	14	—	—	—	39	—	20	3	—	1
Total (91) U.S. Schools	4044	13	1944	2086	48	1199	2383	36	1135	8513	97	4278	983	5	49	400	7	80	288	2	98	150	—	72	838	9	250	80	—	4
Canadian Schools																														
Alberta	14	—	5	—	—	—	—	—	—	14	—	5	9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ecole Polytechnique	3	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	—
McGill	10	—	9	—	—	—	—	—	—	10	—	9	4	—	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Queen's	4	—	—	—	—	—	—	—	—	4	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Toronto	43	—	14	27	—	5	—	—	—	70	—	19	31	—	15	1	—	—	11	—	1	—	—	—	12	—	1	2	—	—
Total (5) Canadian Schools	74	—	28	27	—	5	—	—	—	101	—	33	48	—	20	1	—	—	12	—	1	—	—	—	13	—	1	2	—	—
Total (91) U.S. Schools	4044	13	1944	2086	48	1199	2383	36	1135	8513	97	4278	983	5	49	400	7	80	288	2	98	150	—	72	838	9	250	80	—	4
Grand Total (96 Inst.)	4118	13	1972	2113	48	1204	2383	36	1135	8614	97	4311	1031	5	69	401	7	80	300	2	99	150	—	72	851	9	251	82	—	4

*Enrollment of Undergraduate Engineering Students

Total (5) Canadian Schools	74	—	28	27	—	5	—	—	—	101	—	33	48	—	20	1	—	—	12	—	1	—	—	—	13	—	1	2	—	—
Total (91) U.S. Schools	4044	13	1944	2086	48	1199	2383	36	1135	8513	97	4278	983	5	49	400	7	80	288	2	98	150	—	72	838	9	250	80	—	4
Grand Total (96 Inst.)	4118	13	1972	2113	48	1204	2383	36	1135	8614	97	4311	1031	5	69	401	7	80	300	2	99	150	—	72	851	9	251	82	—	4

*Enrollment of Undergraduate Engineering Students as of November 5, 1946

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1945–46		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Aeronautical	473	6	1195	311	19	1103	162	20	749	94	9	592	4	—	22	9	—	15	37	—	70	1090	54	3746	301	6	50
Agricultural	222	2	263	454	—	147	75	2	86	41	1	48	—	—	—	—	—	—	—	—	—	792	5	544	346	—	6
Architectural	447	16	852	334	25	581	120	21	296	58	16	149	2	—	15	4	—	6	—	—	1	965	78	1900	38	7	14
Ceramic	121	5	109	75	8	123	40	4	83	36	—	50	—	—	—	29	—	12	—	—	—	301	17	377	6	—	2
Chemical	1636	37	2352	1398	41	2688	965	37	2057	594	27	1527	41	1	99	22	—	52	405	14	244	5061	157	9019	738	23	205
Civil	3021	16	6245	1260	30	5180	969	26	3007	428	11	1802	8	—	66	50	—	69	124	4	412	5860	87	16781	686	7	207
Electrical	2713	18	6967	1123	27	5964	648	26	3602	544	20	2114	10	—	44	23	—	50	397	2	492	5458	93	19233	782	12	188
General	1379	3	193	512	2	453	245	1	344	133	4	145	10	—	2	7	—	14	401	8	490	2687	18	1641	119	1	12
Industrial	150	2	521	495	2	885	299	1	848	124	5	439	—	—	2	13	—	25	76	8	210	1157	18	2930	65	—	35
Mechanical	3157	23	7099	2621	32	6131	1211	28	4540	974	31	3391	39	2	160	39	—	98	610	5	583	8651	121	22002	1148	14	71
Metallurgical	173	1	466	111	2	420	87	—	320	54	—	258	—	—	3	5	—	4	58	1	35	488	4	1506	90	—	33
Mining	234	1	433	211	—	428	106	1	272	68	1	184	6	—	—	—	—	—	—	—	—	625	3	1317	36	1	11
Naval Arch. & Marine	16	—	9	19	—	18	5	1	24	8	—	28	—	—	—	—	—	2	—	—	—	48	1	81	31	—	20
Petroleum	103	1	589	95	2	445	48	—	302	28	—	172	—	—	—	3	—	6	—	—	—	277	3	1514	19	—	4
Sanitary	—	—	1	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unclassified	4882	75	12122	469	13	1873	145	—	317	152	3	145	26	—	27	93	27	138	2598	168	2150	8365	286	16772	94	—	7
Total	18727	206	39416	9488	203	26439	5125	168	16849	3336	128	11044	146	3	440	297	27	491	4706	210	4687	41825	945	99366	4499	71	865
Supplementary List	22275	79	—	14189	87	—	8414	69	—	5884	48	—	114	2	—	105	—	—	4356	39	—	55337	324	—	1763	15	168
Grand Total	41002	285	39416	23677	290	26439	13539	237	16849	9220	176	11044	260	5	440	402	27	491	9062	249	4687	97162	1269	99366	6262	86	1033

* See supplementary list.

SUPPLEMENTARY LIST

Enrollment of Undergraduate Engineering Students as of November 5, 1946—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1945–46		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Aeronautical	869	—	—	662	8	—	424	6	—	338	3	—	—	—	—	12	—	—	83	—	—	2388	17	—	185	—	18
Agricultural	275	—	—	145	—	—	86	—	—	57	—	—	—	—	—	4	—	—	—	—	—	567	—	—	5	—	1
Architectural	543	—	—	341	8	—	186	5	—	101	1	—	16	—	—	2	—	—	—	—	—	1189	14	—	13	2	4
Ceramic	39	—	—	28	—	—	26	—	—	7	—	—	—	—	—	1	—	—	—	—	—	101	—	—	6	—	—
Chemical	1603	3	—	1875	12	—	1302	13	—	824	15	—	—	—	—	20	—	—	536	5	—	6160	48	—	283	6	28
Civil	1622	6	—	1860	8	—	954	5	—	545	7	—	—	—	—	3	—	—	710	—	—	5694	26	—	206	1	15
Electrical	4277	9	—	3296	10	—	1616	9	—	963	9	—	—	—	—	10	—	—	1133	13	—	11295	50	—	349	—	27
General	1040	9	—	247	8	—	131	2	—	98	2	—	—	—	—	—	—	—	29	5	—	1545	26	—	19	1	11
Industrial	402	—	—	409	4	—	255	4	—	222	2	—	1	—	—	—	—	—	—	—	—	1289	10	—	35	1	11
Mechanical	3491	17	—	3247	18	—	1881	9	—	1557	7	—	—	—	—	17	—	—	1146	8	—	11339	59	—	547	4	35
Metallurgical	100	1	—	122	—	—	80	1	—	84	—	—	—	—	—	7	—	—	23	1	—	416	3	—	17	—	—
Mining	94	—	—	56	—	—	45	—	—	25	—	—	—	—	—	2	—	—	—	—	—	222	—	—	6	—	—
Naval Arch. & Marine	21	—	—	15	—	—	17	—	—	40	—	—	—	—	—	—	—	—	—	—	—	93	—	—	47	—	—
Petroleum	442	1	—	401	4	—	222	1	—	179	—	—	3	—	—	1	—	—	—	—	—	1248	6	—	24	—	15
Sanitary	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unclassified	7457	33	—	1485	7	—	1189	14	—	844	2	—	94	2	—	26	—	—	696	7	—	11791	65	—	21	—	3
Total	22275	79	—	14189	87	—	8414	69	—	5884	48	—	114	2	—	105	—	—	4356	39	—	55337	324	—	1763	15	168

Total	22275	79	—	14189	87	—	8414	69	—	5884	48	—	114	2	—	105	—	—	4356	39	—	55337	324	—	1763	15	168

Enrollment of Undergraduate Engineering Students as of November 5, 1946—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1945–46		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Akron	47	—	233	10	3	85	7	—	41	3	—	22	3	—	42	—	—	5	—	—	—	71	3	428	3	—	1
Ala. Poly. Inst.	123	5	607	69	7	529	35	4	264	25	2	161	—	—	—	1	—	—	—	—	—	253	18	1561	20	5	47
Ala. Uni.	121	1	823	44	4	284	21	3	174	10	1	87	—	—	—	—	—	—	—	—	—	196	9	1368	32	—	—
Alaska	77	2	64	24	1	22	12	—	11	9	—	8	2	—	2	2	2	2	—	—	—	126	5	109	2	—	—
Alfred	102	3	70	55	4	47	31	2	26	31	—	22	—	—	—	29	—	12	—	—	—	248	9	177	—	—	—
Arizona	79	—	381	45	1	156	16	2	139	12	1	65	—	—	—	1	—	3	—	—	—	153	4	744	7	—	5
Arkansas	455	3	388	271	1	235	136	3	128	50	—	43	—	—	—	—	—	—	—	—	—	912	7	794	16	—	4
Bradley	93	1	407	18	2	120	5	—	37	2	—	10	—	—	—	—	—	—	—	—	—	118	3	574	—	—	1
Brown	312	4	180	163	2	62	78	1	41	111	2	86	—	—	—	4	—	2	—	—	143	668	9	514	68	—	35
Bucknell	190	2	145	128	2	106	85	2	79	60	—	54	—	—	—	—	—	—	—	—	—	463	6	384	26	2	8
Calif. Tech.	54	—	126	38	—	128	34	—	112	113	—	90	—	—	—	—	—	—	—	—	—	239	—	456	—	—	—
Calif. Univ.	322	10	1005	103	2	528	142	4	836	77	3	426	—	—	—	—	—	—	—	—	—	644	19	2795	141	1	23
Calif. Univ. (L. A.)	162	6	661	51	1	346	23	3	182	1	1	15	—	—	—	—	—	—	—	—	—	242	11	1204	—	—	—
Calif. Univ. So.	64	1	415	60	4	450	63	—	388	55	5	295	—	—	—	8	—	19	—	—	—	250	10	1567	113	1	—
Carnegie Inst. Tech.	67	—	271	62	—	478	67	1	351	35	2	211	—	—	—	—	—	—	248	6	321	485	9	1633	46	—	18
Case Sch. Appl. Sci.	99	1	336	62	2	386	49	1	206	29	—	112	—	—	—	—	—	—	686	21	—	925	25	1040	84	2	7
Cincinnati	236	4	423	95	9	605	84	10	360	21	6	131	22	—	64	—	—	—	7	—	5	465	29	1588	24	—	1
Citadel	67	—	137	23	—	78	13	—	48	2	—	31	—	—	—	—	—	—	—	—	—	105	—	294	12	—	4
Clarkson	543	—	—	389	—	329	173	—	147	99	—	83	—	—	—	—	—	—	—	—	—	1204	—	559	44	—	—
Clemson	256	—	364	188	—	415	58	—	245	5	—	221	—	—	—	—	—	—	—	—	—	507	—	1245	38	—	24
Colo. A. & M.	392	—	295	158	—	134	56	1	57	41	—	38	—	—	—	—	—	4	—	—	—	647	1	528	10	—	3
Colo. Mines	51	—	253	54	1	241	29	—	165	15	—	94	—	—	—	—	—	—	—	—	—	149	1	753	—	—	—
Colo. Univ.	288	12	824	138	12	420	66	11	306	49	11	244	—	—	—	4	—	3	—	—	—	545	46	1797	189	—	—
Columbia	—	—	—	—	—	—	26	—	282	24	2	94	—	—	—	45	—	94	—	—	—	95	2	470	—	—	—
Connecticut	119	6	950	35	—	169	19	1	61	12	1	36	—	—	—	—	—	—	—	—	—	185	8	1216	4	—	—

Enrollment of Undergraduate Engineering Students as of November 5, 1946—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1945–46		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Cooper	70	3	86	42	1	87	13	1	35	5	—	20	—	—	—	—	—	—	185	6	363	315	11	591	36	—	4
Cornell	205	4	517	193	11	560	72	5	426	27	8	302	3	—	44	—	—	—	—	—	—	500	28	1849	27	2	92
Delaware	77	1	218	33	—	140	8	—	71	1	—	34	—	—	—	—	—	—	—	—	—	119	1	463	8	—	4
Detroit	193	3	805	63	2	369	48	3	198	29	—	79	24	1	56	3	—	1	340	2	—	700	11	1508	24	—	—
Drexel	189	5	524	112	5	414	40	5	198	24	2	122	23	1	56	5	—	2	—	—	—	393	18	1316	18	—	8
Duke	29	1	89	33	—	114	17	—	62	6	2	175	—	—	—	—	—	—	—	—	—	85	3	440	17	2	40
Fenn	47	1	359	23	2	74	1	—	63	4	—	36	1	—	25	—	—	—	260	12	219	336	15	776	18	—	5
Ga. Tech	395	—	895	226	—	906	83	—	494	59	—	473	—	—	—	34	—	25	—	—	—	797	—	2793	214	—	—
Hawaii	115	4	29	35	—	20	15	—	9	3	—	—	—	—	—	37	—	12	—	—	—	205	4	70	1	—	—
Howard	243	—	207	45	—	26	32	—	18	8	—	5	—	—	—	—	—	—	12	—	10	340	—	256	4	—	1
Idaho	66	2	279	25	—	129	17	—	66	9	—	63	—	—	—	—	—	—	—	—	—	117	2	537	—	—	—
Ill. Inst. Tech	229	2	565	203	1	462	173	2	427	118	2	259	—	—	—	—	—	—	1720	118	1655	2443	125	3368	—	—	—
Iowa Uni	41	—	147	30	1	194	24	1	121	17	2	57	—	—	—	—	—	—	—	—	—	112	4	519	14	—	13
Kansas Uni	198	1	790	84	8	462	49	4	351	12	3	227	—	—	—	1	—	—	—	—	—	344	16	1830	55	2	8
Kentucky	111	5	561	14	2	397	9	6	107	4	4	45	—	—	—	—	—	1	—	—	—	138	17	1111	4	1	4
Louisiana	1200	—	—	119	1	404	60	2	333	41	2	137	—	—	—	3	—	1	—	—	—	1423	5	875	26	1	20
Louisville	14	1	134	40	1	124	21	3	61	13	—	108	—	—	—	—	—	—	—	—	—	88	5	427	59	1	—
Maine	740	2	591	374	3	327	202	2	181	103	1	84	—	—	—	17	—	12	—	—	—	1436	8	1195	13	—	7
Manhattan	130	—	252	75	—	231	24	—	125	8	—	29	—	—	—	—	—	—	—	—	—	237	—	637	11	—	4
Maryland	108	8	1035	23	1	216	12	—	85	8	—	65	—	—	4	—	—	—	—	—	—	151	9	1405	9	—	9

Enrollment of Undergraduate Engineering Students as of November 5, 1946—Continued

Louisiana	1200	—	—	119	1	404	60	2	333	41	2	137	—	—	—	3	—	1	—	—	—	1423	3	873	26	1	20
Louisville	14	1	134	40	1	124	21	3	61	13	—	108	—	—	—	—	—	—	—	—	—	88	5	427	59	1	—
Maine	740	2	591	374	3	327	202	2	181	103	1	84	—	—	—	17	—	12	—	—	—	1436	8	1195	13	—	7
Manhattan	130	—	252	75	—	231	24	—	125	8	—	29	—	—	—	—	—	—	—	—	—	237	—	637	11	—	4
Maryland	108	8	1035	23	1	216	12	—	85	8	—	65	—	—	4	—	—	—	—	—	—	151	9	1405	9	—	9

Enrollment of Undergraduate Engineering Students as of November 5, 1946—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1945–46		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Michigan Uni	298	5	798	188	10	803	102	6	620	147	7	650	—	—	—	12	—	53	—	—	—	747	28	2924	285	4	49
Minnesota	282	4	2152	148	7	1218	98	5	604	48	3	338	1	—	3	7	—	33	—	—	—	584	19	4348	138	4	—
Miss. St. Coll.	111	1	305	62	3	296	26	1	149	12	—	58	—	—	—	—	—	—	—	—	—	211	5	808	7	—	13
Mississippi Uni	124	1	108	51	—	48	15	—	15	6	—	6	—	—	—	—	—	—	—	—	—	196	1	177	—	—	—
Mo. Mines	182	13	855	57	4	389	49	1	299	34	2	194	—	—	—	8	26	35	—	—	—	330	46	1772	39	2	3
Mont. St. Coll.	93	—	568	33	1	248	15	1	109	10	—	73	—	—	—	—	—	—	—	—	—	151	2	998	4	—	4
Nebraska	127	1	607	59	—	318	21	1	210	8	—	93	—	—	2	—	—	—	—	—	—	215	2	1238	20	—	8
Nevada	93	1	191	11	1	63	7	—	48	5	—	23	—	—	—	—	—	3	—	—	—	116	2	328	7	—	—
Newark	123	5	440	90	4	361	48	3	200	27	3	86	—	—	—	2	—	—	323	14	487	613	29	1574	58	3	4
New Hampshire	72	—	231	52	1	189	21	—	86	9	—	37	—	—	—	3	—	2	—	—	—	157	1	545	5	3	11
New Mex. Uni	310	1	262	99	1	69	81	2	56	83	2	73	—	—	—	—	—	—	—	—	—	573	6	460	—	—	—
New York Uni	56	—	172	160	—	224	116	—	283	65	—	227	—	—	—	—	—	—	370	10	878	767	10	1784	88	—	15
No. Dak. Ag. Coll.	370	—	—	112	—	—	61	—	—	22	—	—	1	—	—	—	—	—	—	—	—	596	—	—	—	—	—
No. Dak. Uni	48	2	263	5	—	91	2	1	57	1	—	23	—	—	—	—	—	—	—	—	—	56	3	434	1	—	1
Northeastern	55	5	403	140	6	340	64	1	270	49	1	188	3	—	41	—	—	—	—	—	—	311	13	1242	40	2	16
Northwestern	114	—	180	77	3	248	29	2	180	23	2	106	5	—	75	2	—	13	7	—	—	257	7	802	30	1	23
Notre Dame	167	—	295	139	—	185	32	—	116	13	—	107	—	—	—	—	—	—	—	—	—	351	—	703	31	—	10
Ohio No. Uni	14	1	131	5	—	73	4	—	24	1	—	9	—	—	—	—	—	2	—	—	—	24	1	239	7	—	4
Pennsylvania	236	—	229	205	—	258	103	—	109	45	—	40	—	—	—	—	—	—	—	—	—	589	—	626	16	—	1
Pittsburgh	17	—	593	17	—	547	12	—	269	3	—	185	—	—	—	—	—	—	64	—	339	113	—	1933	13	1	31
Pratt	84	2	313	40	—	111	17	1	62	11	2	24	—	—	—	—	—	—	—	—	—	152	5	510	13	1	8
Rensselaer	254	3	1110	157	14	538	60	3	393	36	4	329	—	—	—	5	—	12	41	9	116	553	33	2498	235	7	32
Rhode Island	52	4	87	26	5	165	11	3	101	6	2	38	—	—	—	—	—	—	—	—	—	95	14	391	2	1	4
Rochester	185	—	108	80	—	74	48	—	41	101	—	76	—	—	—	—	—	—	—	—	—	414	—	299	47	—	—
Rose	56	—	162	11	—	158	13	—	122	9	—	27	—	—	—	—	—	—	—	—	—	89	—	469	11	—	1
Rutgers	101	—	144	28	—	247	18	—	120	—	—	64	—	—	—	1	—	12	—	—	—	148	—	589	9	—	2

Enrollment of Undergraduate Engineering Students as of November 5, 1946—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1945–46		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Santa Clara	104	—	73	86	—	64	46	—	31	19	—	13	—	—	—	—	—	—	—	—	—	255	—	181	2	—	1
So. Carolina	42	1	397	19	1	180	6	1	87	7	—	48	—	—	—	—	—	—	—	—	—	74	3	713	36	1	2
So. Dak. Mines	291	—	260	123	—	107	69	—	56	37	—	33	—	—	—	—	—	—	—	—	—	520	—	456	7	—	6
So. Methodist	404	1	351	233	—	203	87	3	76	42	1	38	—	—	—	12	—	12	—	—	—	778	5	680	22	—	5
So. W. La.	477	1	368	135	—	102	46	1	41	24	1	17	—	—	—	—	—	—	—	—	—	682	3	528	6	—	2
Stevens	607	—	496	314	—	216	131	—	113	108	—	99	—	—	—	—	—	—	—	—	—	1160	—	924	98	—	5
Swarthmore	78	—	44	35	1	29	37	—	32	16	—	13	—	—	—	1	—	—	—	—	—	167	1	118	27	—	—
Syracuse	217	8	536	81	2	259	30	3	106	6	3	61	—	—	—	3	1	8	—	—	—	337	17	970	22	3	6
Tennessee	188	3	842	54	—	401	29	—	144	11	—	86	55	1	17	2	—	2	28	4	—	367	8	1492	19	1	12
Texas A. & I.	82	1	161	19	1	74	5	—	33	3	—	25	—	—	—	1	—	4	—	—	—	110	2	297	3	—	3
Texas Uni.	323	13	1136	144	9	950	68	16	668	60	8	456	2	—	10	—	—	—	—	—	—	597	46	3220	168	2	—
Thayer	69	—	21	47	—	28	106	—	73	77	—	76	—	—	—	—	—	—	—	—	—	299	—	198	41	—	—
Toledo	477	3	318	214	2	184	161	1	143	77	1	61	—	—	—	—	—	—	337	8	151	1266	15	857	12	—	3
Tufts	86	2	147	30	3	169	8	—	75	7	2	156	—	—	—	—	—	—	—	—	—	131	7	547	9	1	—
Tulane	124	1	182	45	—	154	30	—	93	10	1	72	—	—	—	—	—	—	—	—	—	209	2	501	52	1	3
Tulsa	32	—	241	19	—	115	21	3	42	8	—	29	—	—	—	6	—	6	—	—	—	86	3	433	7	—	—
Union	76	—	103	41	—	70	9	—	21	5	—	10	—	—	—	1	—	2	78	—	—	210	—	206	30	—	—
Utah Agr.	7	—	172	56	—	8	31	—	8	9	—	4	—	—	—	—	—	—	—	—	—	103	—	192	—	—	—
Utah Uni.	316	—	399	65	2	258	34	1	223	14	—	108	—	—	—	—	—	—	—	—	—	429	3	988	13	—	21
Vanderbilt	83	—	258	20	—	222	18	2	51	5	—	42	—	—	—	—	—	—	—	—	—	126	2	573	17	1	9
Vermont	23	2	117	10	2	98	4	1	22	1	1	22	—	—	—	—	—	1	—	—	—	38	6	260	1	1	1
Villanova	482	—	—	170	—	130	62	—	56	49	—	40	—	—	—	—	—	—	—	—	—	763	—	226	—	—	—
Va. Mil.	175	—	65	114	—	45	41	—	34	101	—	74	—	—	—	—	—	—	—	—	—	431	—	218	9	—	1
Va. Poly	469	3	1145	134	9	578	43	6	307	21	5	301	—	—	—	—	—	4	—	—	—	667	23	2335	46	1	19
Va. Uni.	19	—	142	13	—	165	13	—	106	2	—	79	—	—	—	—	—	—	—	—	—	47	—	492	46	—	4

Enrollment of Undergraduate Engineering Students as of November 5, 1946—Continued

Vanderbilt	83	—	258	20	—	222	18	2	51	5	—	42	—	—	—	—	—	—	—	—	—	126	2	373	17	1	9
Vermont	23	2	117	10	2	98	4	1	22	1	1	22	—	—	—	—	—	1	—	—	—	38	6	260	1	1	1
Villanova	482	—	—	170	—	130	62	—	56	49	—	40	—	—	—	—	—	—	—	—	—	763	—	226	—	—	—
Va. Mil.	175	—	65	114	—	45	41	—	34	101	—	74	—	—	—	—	—	—	—	—	—	431	—	218	9	—	1
Va. Poly	469	3	1145	134	9	578	43	6	307	21	5	301	—	—	—	—	—	4	—	—	—	667	23	2335	46	1	19
Va. Uni.	19	—	142	13	—	165	13	—	106	2	—	79	—	—	—	—	—	—	—	—	—	47	—	492	46	—	4

Enrollment of Undergraduate Engineering Students as of November 5, 1946—Continued

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1945–46		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.
Wash. St. Coll.	180	—	129	286	—	194	155	3	127	107	4	79	1	—	1	—	—	—	—	—	—	729	7	530	—	—	—
Wash. U. (St. L.)	122	6	233	75	1	407	46	1	206	25	1	75	—	—	—	1	—	—	—	—	—	269	9	921	24	—	4
Wash. Uni.	74	2	733	79	2	398	54	4	312	45	1	239	—	—	—	—	—	—	—	—	—	252	9	1682	123	2	16
Wayne	104	5	625	48	5	219	23	5	117	16	2	65	—	—	—	6	—	77	—	—	—	197	17	1103	11	1	—
Webb Inst.	16	—	9	10	—	3	1	—	8	3	—	7	—	—	—	—	—	—	—	—	—	30	—	27	—	—	16
Wisconsin	217	2	1275	85	5	757	83	3	453	39	4	365	—	—	—	17	—	—	—	—	—	441	14	2850	128	2	—
Wyoming	92	1	354	18	2	114	13	—	91	8	2	60	—	—	—	—	—	—	—	—	—	131	5	619	5	—	8
Yale	400	—	—	527	—	290	306	—	245	219	—	138	—	—	—	15	—	14	—	—	—	1467	—	687	317	—	32
Total (104 Inst.)	18727	206	39416	9488	203	26439	5125	168	16849	3336	128	11044	146	3	440	297	27	491	4706	210	4687	41825	945	99366	4499	71	865
Supplementary list (26)	22275	79	—	14189	87	—	8414	69	—	5884	48	—	114	2	—	105	—	—	4356	39	—	55337	324	—	1763	15	168
Total U.S. Sch. (130)	41002	285	39416	23677	290	26439	13539	237	16849	9220	176	11044	260	5	440	402	27	491	9062	249	4687	97162	1269	99366	6262	86	1033
Canadian Schools																											
Alberta	460	2	342	318	2	251	129	1	59	63	—	13	—	—	—	—	—	—	—	—	—	970	5	665	83	1	—
Ecole	137	—	32	78	—	4	65	—	3	68	—	1	61	—	—	—	—	—	—	—	—	409	—	40	43	—	4
McGill	120	2	337	119	4	308	108	2	113	113	4	61	9	5	2	—	—	—	—	—	—	469	17	821	90	4	15
New Brunswick	182	—	156	182	1	139	56	—	29	35	1	13	—	—	—	—	—	—	—	—	—	455	2	337	33	—	13
Queen's	57	—	327	23	1	265	123	—	148	110	—	58	—	—	—	—	—	—	—	—	—	313	1	798	106	1	9
Toronto	1784	10	—	1614	2	—	544	4	—	291	6	—	10	1	—	—	—	—	—	—	—	4243	23	—	280	—	97
Total Canadian Sch.	2741	14	1194	2334	10	967	1025	7	352	679	11	146	80	6	2	—	—	—	—	—	—	6859	48	2661	635	6	138
Total U.S. Schools	41002	285	39416	23677	290	26439	13539	237	16849	9220	176	11044	260	5	440	402	27	491	9062	249	4687	97162	1269	99366	5627	8	895
Grand Total	43743	299	40610	26011	300	27406	14564	244	17201	9899	187	11190	340	11	442	402	27	491	9062	249	4687	104021	1317	102027	6262	86	1033

Supplementary List of Enrollment, Undergraduate Engineering Students

The following institutions could not separate their veteran enrollment from that of other students.

Engineering Courses	Freshmen (1st year)			Sophomores (2nd year)			Juniors (3rd year)			Seniors (4th year)			5th Year (of 5-yr. Curriculum)			Special Students			Evening Students			Totals			No. of First Degrees Conferred During the Academic Year 1945–46		
	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	V.	M.	W.	% V.	M.	W.	V.
Brooklyn	378	—	—	466	—	—	272	2	—	138	—	—	—	—	—	—	—	—	1902	19	—	3156	21	66	79	1	13
Buffalo	557	—	—	263	4	—	68	2	—	—	—	—	—	—	—	—	—	—	304	—	—	1192	6	88	—	—	—
Catholic	471	—	—	197	4	—	76	—	—	47	2	—	—	—	—	2	—	—	—	—	—	793	6	—	16	—	—
Denver	413	—	—	206	—	—	70	—	—	18	—	—	—	—	—	—	—	—	—	—	—	707	—	92	1	—	—
Florida	769	—	—	274	—	—	142	1	—	43	—	—	—	—	—	—	—	—	—	—	—	1228	1	85	44	—	19
Iowa St. Coll.	1746	—	—	1121	9	—	698	4	—	362	2	—	4	—	—	6	—	—	—	—	—	3937	15	—	264	5	—
Johns Hopkins	280	—	—	264	—	—	118	—	—	64	—	—	—	—	—	2	—	—	1014	—	—	1742	—	—	10	—	4
Kansas St. Coll.	1034	2	—	540	—	—	289	1	—	175	2	—	80	—	—	—	—	—	—	—	—	2118	5	86	65	—	51
Mass. Inst. Tech.	730	—	—	863	—	—	756	—	—	690	—	—	—	—	—	—	—	—	—	—	—	3039	—	—	378	—	—
Mich. St. Coll.	1218	—	—	641	—	—	304	—	—	187	1	—	—	—	—	—	—	—	—	—	—	2350	1	84	22	—	13
N. Y. City Coll.	1500	22	—	945	10	—	626	16	—	416	16	—	—	—	—	—	—	—	1012	16	—	4499	80	55	118	—	5
No. Car. St. Coll.	1173	1	—	1093	4	—	292	3	—	287	—	—	—	—	—	—	—	—	—	—	—	2845	8	87	36	—	—
Ohio State Uni.	2252	11	—	1085	13	—	559	5	—	317	5	—	7	2	—	11	—	—	124	4	—	4355	40	80	55	—	—
Ohio Uni.	—	—	—	106	—	—	50	1	—	30	—	—	—	—	—	—	—	—	—	—	—	186	1	—	—	—	—
Okla. Uni.	1404	15	—	545	10	—	511	10	—	350	2	—	—	—	—	—	—	—	—	—	—	2810	37	—	72	—	—
Oregon	645	3	—	499	2	—	275	4	—	190	—	—	—	—	—	1	—	—	—	—	—	1610	9	65	49	—	—
Pa. St. Coll.	1108	1	—	914	3	—	638	2	—	283	4	—	—	—	—	24	—	—	—	—	—	2967	10	90	81	4	—
Princeton	217	—	—	181	—	—	157	—	—	89	—	—	—	—	—	—	—	—	—	—	—	644	—	—	—	—	—
Purdue	2461	13	—	1746	20	—	1214	10	—	980	9	—	—	—	—	48	—	—	—	—	—	6449	52	87	396	4	—
Rice Inst.	183	—	—	175	—	—	165	—	—	138	—	—	—	—	—	—	—	—	—	—	—	661	—	—	—	—	—
So. Dak. St. Coll.	274	2	—	116	1	—	41	—	—	23	—	—	—	—	—	—	—	—	—	—	—	454	3	80	—	—	—
Texas A. & M.	1806	—	—	1243	—	—	726	—	—	808	—	—	23	—	—	11	—	—	—	—	—	4617	—	76	40	—	63
Texas Tech	744	8	—	390	6	—	193	7	—	164	3	—	—	—	—	—	—	—	—	—	—	1491	24	—	21	—	—
W. Va. Uni.	912	1	—	316	1	—	174	1	—	85	2	—	—	—	—	—	—	—	—	—	—	1487	5	85	16	1	—
24 Inst.	22275	79	—	14189	87	—	8414	69	—	5884	48	—	114	2	—	105	—	—	4356	39	—	55337	324	—	1763	15	168
Harvard*																						172			20		
Stanford*			595						292													887			39		
																						1059			59		
Total supplementary list																						56396			1822	15	168

24 Inst.	22275	79	—	14189	87	—	8414	69	—	5884	48	—	114	2	—	103	—	—	4330	39	—	55337	324		1765	15	166
Harvard*																						172			20		
Stanford*		595						292														887			39		
																						1059			59		
Total supplementary list																						56396			1822	15	168